

PRODUCTION RECOMMENDATIONS FOR GINSENG

Publication 610

Discard old editions of this publication. Each year the appropriate sub-committee of the Ontario Pest Management Research and Services Committee reviews the pesticides listed in this publication. To the best knowledge of the committee, at the time of printing, the pesticide products listed in this publication were:

- federally registered
- classified by the Ministry of the Environment (MOE)

The information in this publication is general

information only. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) does not offer any warranty or guarantee, nor does it assume any liability for any crop loss, animal loss, health, safety or environmental hazard caused by the use of a pesticide mentioned in this publication.

This publication lists a number of brand names of pesticides. It is neither an endorsement of the product nor a suggestion that similar products are ineffective.

The Pesticide Label

Consult each product label before you use a pesticide.

The label provides specific information on how to use the product safely, hazards, restrictions on use, compatibility with other products, the effect of environmental conditions, etc.

The pesticide product label is a legal document. It is against the law to use the product in any other way.

Federal Registration of Pesticide Products

The Pest Management Regulatory Agency (PMRA) of Health Canada registers pesticide products for use in Canada based on following an evaluation of scientific data to ensure that the product has merit and value; and the human health and environmental risks associated with its proposed use are acceptable.

1. Full Registration

Pesticide registrations are normally granted for a period of five years, subject to renewal.

2. Conditional Registration

Conditional registration may be granted for a specified, limited time period, where the registrant agrees to produce additional scientific or technical information, or the pesticide is used for emergency control of a serious pest outbreak.

Maximum Residue Limits

The PMRA has established maximum residue limits (MRLs) for pesticides. Processors or retailers may demand more restrictive limits. Growers should seek advice of their intended market to determine if more restrictive limitations apply. Keep accurate and up-to-date records on pesticide use in each crop.

Supplemental Labels

You **MUST** obtain a supplemental label and follow all the label directions when PMRA approves new uses for a registered pesticide that do not appear on the current label.

Examples of when you must use a supplemental label include:

- **Emergency Use Registration**
- **Minor Use Label Expansion**

You can obtain a copy of a supplemental label from the pesticide manufacturer or pesticide vendor, the grower association that sponsored the emergency registration or minor use, from OMAFRA or PMRA's Pest Management Information Service.

For more information on the federal registration status check the PMRA website at www.pmra-arla.gc.ca or call 1-800-267-6315.

Regulation of Pesticides in Ontario

The MOE is responsible for regulating pesticide sale, use, transportation, storage and disposal in Ontario. Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use, under the *Pesticides Act* and Regulation 63/09.

All Pesticides must be used in accordance with requirements under the *Pesticides Act* and Regulation 63/09, which are available on the e-laws website at www.e-laws.gov.on.ca or call ServiceOntario Publications Toll-Free number: 1-800-668-9938 or 416-326-5300.

Classification of Pesticides

The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to the MOE, the classification of pesticide products before they can be sold or used in Ontario. Once approved by the MOE, classified products are posted on the MOE website: www.ene.gov.on.ca.

Certification and Licensing

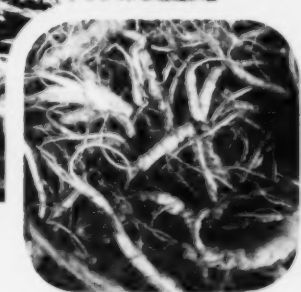
Growers and their Assistants

For information about certification for growers and training for assistants check the Ontario Pesticide Education Program website: www.opec.ca or call 1-800-652-8573.

Commercial Applicators and their Assistants

For more information about exterminator certification and licensing and technician training check the Ontario Pesticide Training & Certification website at www.ontariopesticide.com/OTPC/default.htm or call 1-888-620-9999 or 519-674-1575.

2084-8



PRODUCTION RECOMMENDATIONS FOR GINSENG

Publication 610

Need technical or business information?

Contact the Agricultural Information Contact Centre at:
1-877-424-1300 or ag.info.omafra@ontario.ca

Looking for ginseng information on the Internet?

Check the ginseng page on the OMAFRA website at:
www.ontario.ca/crops

It's one-stop shopping for Factsheets, articles and photos
regarding the production and handling of ginseng in Ontario.

Looking for timely information on production issues and events affecting ginseng and other specialty crops?

Check out the Ginseng and Specialty Crop Report at www.ontario.ca/crops.

It is updated regularly during the growing season.

Sign up for a free subscription on the website.

Information on ordering OMAFRA publications can be found on the inside back cover of this publication.

Acknowledgements

The recommendations in this publication have been prepared in consultation with:

- Ontario Pest Management Research & Services Committee
- Ontario Horticultural Research & Services Committee
- Ontario Soil Management Research & Services Committee
- Ontario Weed Committee

and personnel of:

- Agriculture Development Branch, OMAFRA
- University of Guelph
- Agriculture and Agri-Food Canada

Life cycle and plant diagrams by Tiffany Wybouw.

Contents

1. Using Pesticides in Ontario

Federal Registration of Pesticides	1
Regulation of Pesticides in Ontario	1
Classification of Pesticides	1
Certification and Licensing	1
Pesticide Application Information	2
Re-Entry Intervals	2
Days to Harvest for Food Crops (Preharvest Intervals, Pregrazing and Feeding Intervals)	2
Buffer Zones	2
Protect the Environment	3
Protect Water Sources	3
Prevent Bee Poisoning	3
Manage Drift	3
Pesticide Disposal	4
Empty Pesticide Containers	4
Surplus Spray Mix	4
Surplus Pesticides in Storage	4
Storing Pesticides	4
Pesticide Spills	5

2. Soil Management and Fertilizer Use

Assessing Nutrient Needs	7
Visual Deficiency Symptoms	7
Soil Testing	7
Plant Analysis	9
Soil Micronutrient Tests	10
Fertilizer Recommendations	10
Soil Acidity and Liming	10
Limestone Quality	10
Lowering Soil pH	12
Nitrogen	12
Phosphate and Potash	12
Magnesium	13
Calcium	13
Micronutrient Fertilizers	13
Adjustments to Fertilizer Recommendations	14
Manure	14
Fertilizer Materials	18
Soluble Salts in Farm Soils	18
Toxicity of Fertilizer Materials	18
Managing Soil Organic Matter	19
Cover Crops	20
Choosing a Cover Crop	20
Characteristics of Cover Crops	20
New and Emerging Cover Crops	21

3. Growing Ginseng

Ontario Ginseng Growers Association	23
Introduction	23
History	23
The Ginseng Plant	23
The Principle Growth Stages of Ginseng	25
Germination and Bud Development	25
Leaf Development	25
Root and Bud Formation	25
Flower Head Development	26
Flowering and Fruit Set	26
Fruit Development	26
Senescence	26
Ginseng Seeds and Flowers	27
Flowers	27
Embryo Development	28
Seeds	28
Flower Bud Development	29
Deflowering (Debudding) Ginseng	29
Diseases of Seed Heads and Flower Heads	30
Ginseng Production Systems	30
American Ginseng in Ontario and the <i>Endangered Species Act</i> , 2007	30
Commercialization of Ginseng	31
Planting a Commercial Ginseng Garden	31

4. Harvesting and Handling Ginseng Seeds and Roots

Seeds	37
Harvesting Ginseng Berries	37
Depulping Ginseng Berries	37
Handling Green Seed	37
Stratifying Ginseng Seeds	37
Diseases of Ginseng Seeds	38
Ginseng Chemistry	38
Ginsenosides	38
Polysaccharides	39
Testing for Ginsenosides	39
Roots	40
Harvesting Ginseng Roots	40
Factors Affecting Root Quality	40
Conditioning Ginseng Roots	41
Drying Ginseng Roots	41
Sanitation During Conditioning and Drying	42
Post-Harvest Diseases and Disorders	42
Grading Ginseng by Root Shape	42
Root Shape Classification	43
Ginsenosides and Root Shape	44

CITES Requirements for Exporting Ginseng	44
What Is CITES?	44
How Does CITES Work?	44
CITES and the Export of Ginseng	44
Contacting CITES	45

5. Diseases, Pests and Disorders of Ginseng

Diseases	47
Pythium Diseases of Ginseng	47
Rhizoctonia Diseases of Ginseng	50
Phytophthora Root Rot and Blight of Ginseng	52
Alternaria Diseases of Ginseng	54
Botrytis Blight of Ginseng	56
Fusarium Diseases of Ginseng	57
Cylindrocarpus Diseases of Ginseng	58
Rusty-Root and Rust Spot of Ginseng	61
Fungicide Resistance	62
What Is Resistance?	62
How Does Resistance Develop?	62
What Kind of Product Could Develop Resistance?	63
Using Fungicides Effectively in Ginseng	63
Sanitation	64
Disinfecting Equipment	64
Pesticide Application Technology	64
Pesticide Drift	64
Disease Control	64
Hydraulic Nozzles	65
Sprayer Parameters	65
Canopy Penetration and Coverage	66
Nematodes	66
Cultural and Chemical Control	66
Insects	67
Cutworms	67
European Chafer	67
Four-Lined Plant Bug	68
Pit Scale	69
Leaf Roller	69
Mealy Bugs	69
Stem Borers	70
Aphids	70
Planthoppers	70
Other Pests	71
Slugs	71
Millipedes	71
Rodents	72
Weeds	72
Abiotic Disorders of Ginseng	72
Heat Stress	72
Air Pollution	73
Boron Toxicity	73
Herbicide Drift	73
Foliar Fertilizers Mixed With Fungicides	73
Foliar Fertilizers Containing Cytokinins	73
Low-Temperature and Freeze Damage	73

6. Pest Control Recommendations

Table 6-1. Ginseng Seed Treatments	75
Table 6-2. Preplant Fumigation of Ginseng in Ontario	75
Table 6-3. Insect Control Recommendations for Ginseng in Ontario	76
Table 6-4. Weed Control Recommendations for Ginseng in Ontario	76
Table 6-5. Slug Control Recommendations for Ginseng in Ontario	77
Table 6-6. Disease Control Recommendations for Ginseng in Ontario	77

7. Appendices

Appendix A. Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Specialty Crop Advisory Staff	79
Appendix B. Diagnostic Service	80
Appendix C. Phytosanitary Certificates	82
Appendix D. Other Contacts	82
Appendix E. Accredited Soil Testing Labs in Ontario	83
Appendix F. Ontario Ministry of the Environment Regional Contact Information	83
Appendix G. The Metric System	85

8. Colour Plates	89
------------------------	----

Tables

2. Soil Management and Fertilizer Use

Table 2-1.	OMAFRA-Accredited Soil Tests	7
Table 2-2.	Soil Test Nutrient Ratings	8
Table 2-3.	Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH	11
Table 2-4.	Example Calculation of the Fineness Rating of a Limestone	11
Table 2-5.	Phosphorus Requirements for Ginseng on Mineral Soils	12
Table 2-6.	Potassium Requirements for Ginseng on Mineral Soils	13
Table 2-7.	Manganese Availability Index Interpretation	13
Table 2-8.	Zinc Availability Index Interpretation	14
Table 2-9.	Adjustment of Nitrogen Requirement Where Crops Containing Legumes Are Plowed Down	14
Table 2-10.	Available Nutrients and Value for Manure From Various Livestock Types – Solid Manure	15
Table 2-11.	Approximate Ammonium-Nitrogen Levels Available by Livestock Type	16
Table 2-12.	Estimated Percentage of Ammonium-Nitrogen Lost Due to Weather and Soil Conditions	16
Table 2-13.	Calibrating Manure Spreaders	17
Table 2-14.	Densities of Different Types of Manure ..	17
Table 2-15.	Determining Minimum Separation Distance From Watercourses	17
Table 2-16.	Fertilizer Materials — Primary Nutrients ..	18
Table 2-17.	Fertilizer Materials — Secondary and Micronutrients	19
Table 2-18.	Soil Conductivity Reading Interpretation ..	19
Table 2-19.	Matching Cover Crop Choices to Function ..	20
Table 2-20.	Choosing a Cover Crop	21
Table 2-21.	Characteristics of Cover Crops Grown in Ontario	22

3. Growing Ginseng

Table 3-1.	Seeding Rate and Equivalent 100% Plant Stand in the Seedling Year	29
Table 3-2.	Deflowering Decision Matrix	29
Table 3-3.	The Range of Nutrient Conditions at Wild Ginseng Sites in Ontario	33
Table 3-4.	Critical Soil Temperatures in Ginseng Gardens	35

4. Harvesting and Handling Ginseng Seeds and Roots

Table 4-1.	The Relationship of Production System and Total Ginsenosides by Weight in Ginseng Roots	39
Table 4-2.	The Relationship of Production System to the Amount of Specific Ginsenosides in Ginseng Roots	39

5. Diseases, Pests and Disorders of Ginseng

Table 5-1.	Quick Disease Reference for Ginseng ...	60
Table 5-2.	Disinfecting Equipment	64
Table 5-3.	The Impact of Droplet Size	65

6. Pest Control Recommendations

Table 6-1.	Ginseng Seed Treatments	75
Table 6-2.	Preplant Fumigation of Ginseng in Ontario	75
Table 6-3.	Insect Control Recommendations for Ginseng in Ontario	76
Table 6-4.	Weed Control Recommendations for Ginseng in Ontario	76
Table 6-5.	Slug Control Recommendations for Ginseng in Ontario	77
Table 6-6.	Disease Control Recommendations for Ginseng in Ontario	77

Figures

3. Growing Ginseng

Figure 3-1.	Diagram of a typical <i>Panax quinquefolius</i> plant	24
Figure 3-2.	Germination of Ginseng Seed	26
Figure 3-3.	Ginseng Seed Head With Concurrent Flower Buds, Flowers and Berries	27

4. Harvesting and Handling Ginseng Seeds and Roots

Figure 4-1.	Spider-Grade Root	43
Figure 4-2.	Fibre-Grade Root	43
Figure 4-3.	Chunk-Grade Root	43
Figure 4-4.	Forked-Grade Root	43
Figure 4-5.	Pencil-Grade Root	43

5. Diseases, Pests and Disorders of Ginseng

Figure 5-1.	Life Cycle of <i>Pythium</i> on Ginseng	48
Figure 5-2.	Life Cycle of <i>Rhizoctonia</i> on Ginseng ..	50
Figure 5-3.	Life Cycle of <i>Phytophthora</i> on Ginseng ..	52
Figure 5-4.	Life Cycle of <i>Alternaria</i> on Ginseng ..	54
Figure 5-5.	Life Cycle of <i>Botrytis</i> on Ginseng	56

Plates

Plate 1.	The emerging root and shoot of ginseng	89
Plate 2.	Buds on a 4-year-old ginseng root	89
Plate 3.	Two-year-old ginseng emerging	89
Plate 4.	Ginseng seedlings with leaves unfolded	89
Plate 5.	Developing ginseng seeds	89
Plate 6.	Ripe ginseng berries	89
Plate 7.	Ginseng berries ready to harvest	90
Plate 8.	Tub of "green seeds" after depulping	90
Plate 9.	Immature ginseng embryo	90
Plate 10.	Stratified ginseng seeds	90
Plate 11.	High-precision air seeder	90
Plate 12.	Formation of raised beds before planting	90
Plate 13.	Straw being applied to newly seeded ginseng	91
Plate 14.	Flower stalks infected with <i>Alternaria</i>	91
Plate 15.	Berries infected with <i>Botrytis</i>	91
Plate 16.	<i>Botrytis</i> conidia on ginseng berries	91
Plate 17.	A stand of wild ginseng in an Ontario forest	91
Plate 18.	Wild ginseng root	91
Plate 19.	Perimeter trench for removal of surface water	92
Plate 20.	Phytophthora infection in a waterflow area	92
Plate 21.	Water standing in trenches	92
Plate 22.	Leaf symptoms of boron toxicity	92
Plate 23.	Rye allelopathy in ginseng	92
Plate 24.	Nurse crop of oats in newly seeded ginseng	92
Plate 25.	Ginseng garden with wooden lath shade	93
Plate 26.	Ginseng garden with low cloth shade	93
Plate 27.	Ginseng garden with high cloth shade	93
Plate 28.	Mechanical depulper	93
Plate 29.	Checking the seed in a buried seedbox	93
Plate 30.	Infected seed with decay near the embryo	93
Plate 31.	Rust spot in ginseng seed	94
Plate 32.	<i>Cylindrocarpus</i> sporodochia on seeds	94
Plate 33.	<i>Pythium</i> -infected seed	94
Plate 34.	Bacterial seed decay	94
Plate 35.	Bacteria oozing from the micropore	94
Plate 36.	Ginseng roots on the soil surface after digging	94
Plate 37.	Harvested root packed in baskets	95
Plate 38.	Washed roots on drying trays	95
Plate 39.	Drying trays	95
Plate 40.	Open ginseng dryer showing stacked trays	95
Plate 41.	Dried ginseng root with a creamy interior	95
Plate 42.	Red veins running vertically along dried root	95
Plate 43.	Close look at the red veins	96
Plate 44.	Cross-section of the red veins	96
Plate 45.	Dried roots with areas of <i>Rhizopus</i> infection	96
Plate 46.	Geotrichum mould improperly dried root	96
Plate 47.	Damping-off of ginseng seedlings	96
Plate 48.	<i>Pythium</i> infections on feeder roots	96
Plate 49.	<i>Pythium</i> damage on tap root tips	97
Plate 50.	Buds invaded by <i>Pythium</i>	97
Plate 51.	Feeder roots severely pruned by <i>Pythium</i>	97
Plate 52.	Proliferation of feeder roots from <i>Pythium</i>	97
Plate 53.	Two-year old roots infected with <i>Rhizoctonia</i>	97
Plate 54.	<i>Rhizoctonia</i> lesions on roots	97
Plate 55.	<i>Rhizoctonia</i> lesion on a 4-year old root	98
Plate 56.	<i>Rhizoctonia</i> bud rot affects emergence	98
Plate 57.	Garden with circles of missing plants	98
Plate 58.	Pinkish-brown rot typical of phytophthora	98
Plate 59.	Roots decayed by phytophthora	98
Plate 60.	Leaves of plants with phytophthora root rot	98
Plate 61.	One leaf wilting due to phytophthora	99
Plate 62.	Leaflet infected with phytophthora	99
Plate 63.	Foliar phytophthora affects the entire top	99
Plate 64.	Plants missing around leaking sprinkler	99
Plate 65.	<i>Phytophthora</i> -infected plants by trenches	99
Plate 66.	<i>Alternaria</i> stem lesions	99
Plate 67.	<i>Alternaria</i> stem canker on seedlings	100
Plate 68.	<i>Alternaria</i> lesions on leaves	100
Plate 69.	Severe <i>alternaria</i> stem infection	100
Plate 70.	<i>Botrytis</i> sclerotia on the straw and old stems	100
Plate 71.	Decaying leaves droop onto healthy leaves	100
Plate 72.	<i>Botrytis</i> infections of the leaves	100
Plate 73.	<i>Botrytis</i> on the stem after freeze damage	101
Plate 74.	<i>Botrytis</i> root rot	101
Plate 75.	Disappearing root rot	101

Plate 76. <i>Cylindrocarpon</i> root rot on new seedlings	101	Plate 113. Leaf symptoms of heat stress	107
Plate 77. <i>Cylindrocarpon</i> infections in older seedlings	101	Plate 114. Air pollution damage to leaves	107
Plate 78. Rusty netting due to <i>cylindrocarpon</i>	101	Plate 115. Glyphosate damage to ginseng	108
Plate 79. Healthy leaves with rotting root	102	Plate 116. Foliar burn from fertilizer/fungicide mix	108
Plate 80. Wilt accompanied by drying of the leaves	102	Plate 117. Cytokinin damage to leaves	108
Plate 81. Scaly lesion is typical of <i>cylindrocarpon</i> rot	102	Plate 118. Leaf puckering caused by chilling	108
Plate 82. Underlayer of orange crumbly rot	102	Plate 119. Low temperature stem kinking	108
Plate 83. Weak strains of <i>cylindrocarpon</i> root rot	102	Plate 120. Swollen and split stems after freezing	108
Plate 84. Symptoms of <i>Cylindrocarpon</i> plus <i>Rhizopus</i>	102		
Plate 85. Ginseng abiotic rust spot	103		
Plate 86. Abiotic rust spot causing deep decay	103		
Plate 87. Superficial rust spot	103		
Plate 88. Root knot nematodes galls on ginseng	103		
Plate 89. Ginseng seedlings severed by a cutworm	103		
Plate 90. Severed seedling upside down on the straw	103		
Plate 91. European chafer "white grub"	104		
Plate 92. White grub damage to seedlings	104		
Plate 93. White grub damage in a 2-year garden	104		
Plate 94. Adult four-lined plant bug	104		
Plate 95. Seedling damage from four-lined plant bugs	104		
Plate 96. Older leaves affected by four-lined plant bug	104		
Plate 97. Pit scale on a ginseng stem	105		
Plate 98. Feeding damage from pit scales	105		
Plate 99. Leaf folded by leaf roller caterpillar	105		
Plate 100. Larva of one of the leaf roller moths	105		
Plate 101. <i>Acanthococcus</i> mealybugs	105		
Plate 102. Mealybug egg case with eggs	105		
Plate 103. Mealybug feeding damage	106		
Plate 104. European corn borer inside a ginseng stem	106		
Plate 105. Unknown aphid species on a ginseng stem	106		
Plate 106. Planthopper nymphs with waxy secretions	106		
Plate 107. Stem chewed by slugs	106		
Plate 108. Leaves chewed by slugs	106		
Plate 109. Slug feeding damage on berries	107		
Plate 110. Slug feeding damage on roots	107		
Plate 111. Millipedes found in a ginseng field	107		
Plate 112. Stem showing mouse chewing damage	107		

1. Using Pesticides in Ontario

**Read the latest product label
before using a pesticide!**

**Review the Grower Pesticide
Safety Course Manual.**

Keep detailed spray records.

Federal Registration of Pesticides

Before a pesticide can be sold or used in Ontario, it must be registered under the federal *Pest Control Products Act* (PCP Act) and be classified under the provincial *Pesticides Act*. The Pest Management Regulatory Agency (PMRA) of Health Canada registers pesticides for use in Canada following an evaluation of scientific data to ensure that the product has merit and value. It also ensures that the human health and environmental risks associated with its proposed use are acceptable.

The PMRA re-evaluates registered pesticides to determine whether today's health and environmental protection standards are still met when following the label directions. Outcomes of a re-evaluation can be:

- no change in the registration
- label amendments (i.e., changes to personal protective equipment requirements, re-entry intervals and buffer zones)
- modifications to existing maximum residue limits (MRLs)
- elimination or phasing-out of certain uses or formulations
- no further acceptance of the registration

The pesticide label is a legal document. It prescribes how the pesticide can be legally used. Off-label use is prohibited. It is against the law to use the pesticide in any other way or on any other crop or pest than as specified on the label. Labels for all registered pesticides are under Label Search on the PMRA website at www.pmra-arla.gc.ca. Ensure you have the most current label and are aware of any re-evaluation decisions.

Regulation of Pesticides in Ontario

The Ministry of the Environment (MOE) is responsible for regulating the sale, use, transportation, storage and disposal of pesticides in Ontario. Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use, under the *Pesticides Act* and Regulation 63/09. All pesticides must be used in accordance with requirements under the *Pesticides Act* and Regulation 63/09, which are available on the e-laws website at www.e-laws.gov.on.ca or by calling Service Ontario at 1-800-668-9938 or 416-326-5300.

Classification of Pesticides

The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to the MOE the classification of pesticide products before they can be sold or used in Ontario. Pesticide products are classified on the basis of their toxicity, environmental or health hazard, persistence of the active ingredient or its metabolites, concentration, usage, federal class and registration status. This classification system provides the basis for regulating the distribution, availability and use of pesticide products in Ontario. Once approved by the MOE, classified products are posted on the MOE website at www.ene.gov.on.ca.

The Ontario pesticide classification system changed from 6 Schedules to 11 Classes (Regulation 63/09).

Certification and Licensing Growers and Their Assistants

For information about certification for growers and training for assistants to growers, visit the Ontario Pesticide Education Program website at www.opecp.ca or call 1-800-652-8573.

Commercial Applicators (Exterminators) and Their Assisting Technicians

For more information about exterminator licensing and technician training, visit the Ontario Pesticide Training & Certification website at www.ontariopesticide.com/OPTC/default.htm or call 1-888-620-9999 or 519-674-1575.

For more information about pesticide regulations, certification and licensing, see:

- Inside front cover of this publication
- Pest Management Regulatory Agency (PMRA) website: www.pmr-arla.gc.ca
- PMRA Pest Management Information Service: 1-800-267-6315 (from within Canada) or 1-613-736-3799 (from outside Canada)
- Ontario Ministry of the Environment (MOE) website: www.ene.gov.on.ca
- Regional MOE Pesticides Specialist (See Appendix F. *Ontario Ministry of the Environment Regional Contact Information*, on page 85.)
- Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) website: www.ontario.ca/omafra
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) website: www.opecp.ca
- Ontario Pesticide Training & Certification website: www.ontariopesticide.com/OPTC/default.htm

Pesticide Application Information

When you decide to use a pesticide, choose the most appropriate formulation and application method for your situation. Use only a properly calibrated sprayer. Choose less toxic alternatives when possible. Take all possible precautions to prevent the exposure of people and non-target organisms to the pesticide. Read the most current pesticide label thoroughly before application. The label provides important information, such as:

- directions for use (rates of application, crops it can be used on, target pests, crop rotation restrictions, total number of applications, droplet size/nozzle type, application equipment, timing and ideal weather conditions)
- required personal protective equipment
- health hazards and toxicity
- re-entry intervals
- buffer zones
- special warnings
- steps to be taken in case of an accident
- disposal

For more information on hazards, consult the Material Safety Data Sheet (MSDS) or contact the manufacturer.

Re-Entry Intervals

The re-entry interval, also referred to as Restricted Entry Interval (REI), is the period of time following a pesticide application during which workers must not enter the treatment area without wearing protective clothing and personal protective equipment. This allows any pesticide residue and vapours to dissipate from the treatment location (e.g., field), preventing the possibility of inadvertent pesticide exposure.

The PMRA reviews each pesticide to determine whether the label should include a specific re-entry interval. If the re-entry interval is not stated on the label, assume that the spray solution must be dry before re-entry can occur. Some pesticides have labels that carry a warning about working in treated crops. Follow the label recommendations.

Days to Harvest for Food Crops (Preharvest Intervals, Pregrazing and Feeding Intervals)

These intervals state the minimum time that must pass between the last pesticide application and the harvesting of the crop, or the grazing or cutting of the crop for livestock feed. If you harvest a crop before the preharvest interval (PHI) has passed, there may be pesticide residues in excess of the maximum residue limits (MRLs) set by PMRA.

To avoid exceeding the maximum residue limits, always follow the directions on the label.

Buffer Zones

Buffer zones are areas left untreated to protect an adjacent sensitive area, such as sensitive terrestrial and aquatic habitats, well heads, non-target crops and areas where children play.

Leave a suitable buffer zone between the treatment area and adjacent sensitive areas. Buffer zones may vary depending on the method of application (i.e., aerial, field boom, hand-held sprayer). Some pesticide labels specify buffer zone requirements. Check the pesticide label for the type of buffer zone required.

Sensitive terrestrial habitats include hedgerows, grasslands, shelterbelts, windbreaks, forested areas, woodlots, vegetative strips, etc.

Sensitive aquatic habitats include lakes, reservoirs, streams, creeks, ditches, marshes, wetlands, ponds, commercial fish ponds, etc.

Setback Distances for Water Bodies

It is an offence under the federal *Fisheries Act* to introduce into water any material that may be harmful to fish or fish habitat. To protect these waters, applicators must determine a suitable setback distance between the area to be protected and the area where pesticide treatments are planned (if one is not specified on the pesticide label). The protected area includes the water body as well as adjacent riparian (riverbank) areas that contribute to fish food and habitat.

Protect the Environment

Protect Water Sources

According to the British Crop Protection Council (BCPC), between 40% and 70% of surface water pesticide contamination comes from mixing and filling areas.

You should load or mix pesticides on impermeable surfaces that are safely away from watercourses or environmentally sensitive areas. Drainage and run-off should be collected and disposed of safely (*Your Guide to Using Pesticides*, BCPC 2007).

Clean your spray equipment away from wells, ponds, streams and ditches. Apply the diluted rinse water (usually at a ratio of 10 to 1) to the treatment area (crop) but do not exceed the pesticide rate recommended on the label.

For more information on protecting water sources, see:

- OMAFRA Factsheet, *Pesticide Contamination of Farm Water Supplies: Recommendations on Avoidance, Cleanup and Responsibilities*, Order No. 00-099
- OMAFRA Factsheet, *Groundwater – An Important Rural Resource: Protecting the Quality of Groundwater Supplies*, Order No. 06-115
- OMAFRA/Agriculture and Agri-Food Canada booklet, *Best Management Practices — Pesticide Storage, Handling and Application*, Order No. BMP13

Do not make a direct connection between any water supply (e.g., public supply, wells, watercourse or pond) and a spray tank. Use an anti-backflow device or intermediate system to prevent back-siphoning that could contaminate the water supply.

Immediately contain and clean up any spills to prevent contamination to water sources.

Check the pesticide label for specific instructions on water source protection.

Prevent Bee Poisoning

It is important to protect bees when spraying insecticides. Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops also offer bees sources of nectar for honey production.

Read each pesticide label for specific precautions regarding bees. Choose less toxic alternatives when possible. Most organophosphate and carbamate insecticides are highly toxic to bees.

Advise local beekeepers before you apply a pesticide, so that they may take additional precautions to protect their bees. Contact the Provincial Apiarist at 1-888-466-2372, ext. 63595, for a list of the beekeepers in your area. Follow guidelines regarding spray timing to prevent unnecessary poisonings. For more information on preventing bee poisoning, see the "apiculture" section of the OMAFRA website at www.ontario.ca/crops.

Manage Drift

- Do not spray when wind speeds are high or gusty. These conditions will favour spray drift. Check pesticide labels for allowable wind speeds for spraying applications. Some labels may not provide this specific information. Constantly monitor wind conditions during spraying, using a good quality wind meter. Record the wind speed and direction. As wind conditions change, you may need to make adjustments to further reduce the drift potential, such as adjusting water volume upwards, minimizing nozzle-to-target distance, changing nozzle technology, changing fields because of surrounding influences or stop spraying until conditions improve.
- Do not spray during periods of dead calm. Periods of dead calm usually occur in early morning or late evening, at which time the temperature is usually cooler and the relative humidity is typically higher. The combination of these factors can result in drift-sized droplets staying in the field. When the wind picks up, these spray droplets can move away from the target area, possibly causing injury to adjacent non-target areas.

- Use the recommended sprayer output (water volume).
- Use a nozzle that will produce the appropriate droplet size if specified on the pesticide label.
- Use the most appropriate nozzle for the type of application. Where practical, use air induction/venturi nozzles, which significantly reduce drift when compared to conventional nozzles.
- Check the height of the boom to the target and minimize the distance as much as possible while still maintaining spray uniformity.
- Follow buffer zone requirements for the protection of adjacent sensitive areas as outlined on the pesticide label.
- Use spray plume protection where practical or available (hoods, shrouds, screens and air curtains).
- Use drift-reducing adjuvants in the spray tank as directed on the label.
- Use wick weeders instead of spraying when possible.
- Use non-volatile pesticide formulations or products.

For more information about spray drift, see:

- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices – Pesticide Storage, Handling and Application*, Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) videos *How to Manage Spray Drift and Spray Drift Reduction Through Air Induction*, available at www.opecp.ca/Educational/EducationalMaterials.htm

Pesticide Disposal

Empty Pesticide Containers

Never reuse empty containers. Puncture the cleaned empty containers to make them unusable.

The Ontario Empty Pesticide Container Recycling Program is available to growers and commercial applicators. Through this program, you can return cleaned and triple-rinsed plastic/metal pesticide containers (up to 23 L for plastic and 20 L for metal) to pesticide container depots located throughout the province. Remove the paper booklet from the pesticide container before recycling. To locate the closest pesticide container recycling depot, call the Ontario Pesticide Education Program at 1-800-652-8573, your local dealer or municipality, or visit the CropLife Canada website at www.croplife.ca.

Surplus Spray Mix

The best way to dispose of any excess spray mix is to find other fields that require an application of this pesticide. Before spraying, check the label to make sure the pesticide is registered for use on that crop.

If you cannot find another field to spray, dilute the remaining spray mix by adding 10 parts of water for each 1 part of spray mix. The diluted solution can be safely applied to the original treated area as long as you do not exceed the pesticide rate recommended on the label. Be sure to check the label for any restrictions about crop rotation, days to harvest or surplus spray mix disposal.

Never re-spray the treated field with undiluted spray mix. Spraying an area twice will double the recommended pesticide rate. This may cause illegal pesticide residues in the harvested crop or harmful residues in the soil that can cause crop damage.

Surplus Pesticides in Storage

Be sure to safely dispose of pesticides that you do not need or cannot use. Options for proper disposal include:

- Contact the supplier. It is sometimes possible to return unused pesticide if it is still in its original, unopened container.
- Hire a waste hauler who is licensed under Part V of the *Environmental Protection Act* to carry hazardous wastes. Look in the yellow pages of your telephone directory under Liquid Waste Removal.
- Check your local paper or visit the CropLife Canada website (www.croplife.ca) for upcoming Obsolete Pesticide Collection Days.
- Contact your municipality to see if any waste collection days are scheduled and verify whether quantities of agricultural pesticides will be accepted.

Storing Pesticides

Ontario's *Pesticides Act* and Regulation 63/09 provide details on storage requirements for storage facilities. The storage requirements that must be followed are dependent on which classes of pesticides you store.

For more information about storing pesticides, see:

- OMAFRA Factsheet, *Farm Pesticide Storage Facility*, Order No. 07-059
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices — Pesticide Storage, Handling and Application*, Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) *Grower Pesticide Safety Course Manual*, available at www.opep.ca/Educational/EducationalMaterials.htm

Pesticide Spills

If a pesticide spill causes, or is likely to cause, an adverse effect that is greater than that which would result from the proper use of the pesticide, you must notify the Ministry of the **Environment Spills Action Centre at 1-800-268-6060** (24 hours a day, 7 days a week) and your municipality.

A spill is defined as a discharge of pollutant that is abnormal in quality or quantity, from or out of a structure, vehicle, or other container, into the environment. An incident such as an overturned pesticide sprayer that results in the loss of the spray solution to the environment is an example of a spill. A pesticide container that ruptures and leaks its contents is another example of a spill. The discharge or spraying of a pesticide in an unapproved area, commonly referred to as an overspray, is also considered a spill.

Before you begin to clean up a spill of any nature, remember to protect yourself against pesticide exposure. Wear the proper protective clothing and personal protective equipment. If the spill occurs

inside an enclosed area (e.g., a pesticide storage area or a vehicle during transport), ventilate the area first. Once you have protected and/or removed yourself and other persons or animals from the spill site, take additional measures to stop the spill at the source and prevent it from spreading and/or contaminating watercourses. Specific precautions, emergency contact information and first aid procedures may be found on the label.

For minor spills, it may be possible to remediate the problem:

- **For a liquid spill** – Cover the spill with a thick layer of absorbent material such as kitty litter, vermiculite or dry soil. Sweep or shovel the material into a waste drum and dispose of the contents as you would a hazardous waste.
- **For a dust, granular or powder spill** – Sweep or shovel the material into a waste drum and dispose of the contents as you would a hazardous waste.

For major spills, it is essential to stop the spill from spreading. The clean-up guidelines above may not be appropriate for all spill situations. Once you have contained the spill, follow directions from the manufacturer and regulatory authorities on cleaning the contaminated area.

For information on preventing spills, see:

- OMAFRA Factsheet, *Ways to Avoid Pesticide Spills*, Order No. 96-025
- OMAFRA/Agriculture and Agri-Food Canada booklet, *Best Management Practices — Pesticide Storage, Handling and Application*, Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) *Grower Pesticide Safety Course Manual*, available at www.opep.ca/Educational/EducationalMaterials.htm

For pesticide poisonings and pesticide injuries call:

Poison Information Centre:

1-800-268-9017

(TTY) 1-877-750-2233

For more information, see inside back cover on Emergency and First Aid Procedures for Pesticide Poisoning.

2. Soil Management and Fertilizer Use

For a complete guide to soil fertility, see OMAFRA Publication 611, *Soil Fertility Handbook*.

Soil fertility is an important component in the production of high yielding, top-quality ginseng. However, soil fertility is only one part of a crop management program. The effectiveness of a soil fertility program will depend on careful soil and water management, as well as crop protection. Developing a good, sound soil fertility program begins with assessing the crop and the soil's nutrient needs.

Assessing Nutrient Needs

There are three ways to assess soil and crop fertility:

- visual deficiency symptoms
- soil testing
- plant analysis

Visual Deficiency Symptoms

Leaf symptoms are helpful for evaluating some nutrient deficiencies. Unfortunately, by the time deficiency symptoms are visible, yield losses may have already occurred. Visual deficiency symptoms may also be easily confused with other production problems, such as herbicide injury, leaf and root diseases, nematodes, insect damage, compaction or air pollution. Furthermore, nutrient deficiency symptoms in some crops can be diagnosed based on whether they show up on new or old leaves. This is not possible for ginseng because all of the leaves on the plant are the same age. Suspected visual deficiencies can often be confirmed with leaf or plant analysis. Some visual deficiency symptoms are described in the individual nutrient sections beginning on page 32.

Soil Testing

Soil testing in Ontario is done by commercial soil-testing laboratories, using tests accredited by OMAFRA (see Table 2-1, *OMAFRA-Accredited Soil Tests*, this page). OMAFRA-accredited soil tests are not available for boron, copper, iron or molybdenum. Plant analysis is generally a better indicator of deficiencies of these nutrients. For a list of accredited soil-testing laboratories in Ontario, see Appendix E, *Accredited Soil Testing Labs in Ontario*, on page 84.

Table 2-1. OMAFRA-Accredited Soil Tests

See Appendix E, on page 84,
for a list of accredited labs in Ontario.

Materials	What Is Analyzed ¹
Accredited Soil Tests	
Soils for field-grown crops, commercial turf, etc.	plant-available phosphorus, potassium, magnesium, zinc and manganese pH lime requirement
Other Tests From Accredited Laboratories	
Greenhouse media	plant-available nitrogen, phosphorus, potassium, calcium, magnesium pH total salts
Nutrient solutions, water	plant-available nitrogen, phosphorus, potassium, calcium, magnesium pH total salts sulphates chlorides

¹ Soil organic matter tests can be useful for herbicide recommendations or for evaluating soil quality but are not accredited tests.

When to Sample

Ginseng growers usually prepare land for ginseng 1–2 years in advance of seeding. Ginseng is seeded in the fall. Test soil to be used for ginseng production in the fall prior to the preplant year. If adjustments to pH and/or fertility are made, do additional testing in the summer of the preplant year (see Table 2-9, *Adjustment of Nitrogen Requirement Where Crops Containing Legumes Are Plowed Down*, on page 14).

Sample each field once every 2 or 3 years. Potash levels can change quickly on sandy soils where large amounts of nutrients are removed by the crop, especially if there is limited crop residue left on the soil. Consequently, soil sampling earlier than the fall before the preplant year may not provide an accurate indication of soil fertility levels.

Taking a Soil Sample

The accuracy of a soil test report and the resulting recommendations depend on properly taking, preparing and submitting a soil sample. The following items are needed to sample soil:

- a soil probe or a shovel

- a clean plastic pail. Avoid using galvanized metal pails; these will contaminate the sample for micronutrient analysis, particularly zinc.
- sample bags and boxes, usually available from the soil laboratory
- a pen or marker

Sample each garden separately. Separate large gardens and gardens with considerable variation into smaller sections. Each garden section should have relatively the same soil texture, topography, organic matter and cropping history.

Micronutrient deficiencies frequently occur in small patches in fields. In these cases, analysis of soil or plants taken from the entire garden is unlikely to identify the problem. Sample problem areas separately. When sampling a problem area, be sure to take a comparison sample from an adjacent good area.

For a basic test, sample soil cores to a depth of 15 cm. Nitrate-nitrogen samples are taken to a depth of 30 cm. For both tests, take at least 20 soil cores for fields up to 5 ha in size. Take proportionately more cores for gardens larger than 5 ha. The more cores you sample, the more reliable the measure of the fertility in the garden. One sample should not represent more than 10 ha.

Travel the area sampled in a zigzag pattern to provide a good variety of sampling sites. Avoid sampling recent fertilizer bands, dead furrows, areas adjacent to gravel roads or areas where lime, manure, compost or crop residues have been piled.

Break up the lumps. Mix the soil well before sending a soil sample for testing. Approximately 2 mL of each sample are used for the analysis, so a well-mixed sample will provide greater accuracy. Fill a clean plastic bag with approximately 500 g of soil and place it into the box. Be sure to clearly mark the sample with all the necessary information including sample number, farm name, date, etc.

Interpreting the Results

The OMAFRA-accredited soil-testing program provides recommendations for nitrogen, phosphate, potash, magnesium, zinc and manganese fertilizer. It also gives recommendations for the amount and type of lime to be applied, if required. OMAFRA-recommended fertilizer rates are provided starting on page 12 and in Table 2-5, *Phosphorus Requirements for Ginseng on Mineral Soils*, on page 12, and Table 2-6, *Potassium Requirements for Ginseng on Mineral Soils*, on page 13. These recommendations can produce the highest economic yields when accompanied by good or above-average crop production management.

Table 2-2. Soil Test Nutrient Ratings

Response Category	Probability of Profitable Response to Applied Nutrients
High Response (HR)	high (most of the cases)
Medium Response (MR)	medium (about half the cases)
Low Response (LR)	low (few of the cases)
Rare Response (RR)	rare (very few of the cases)
No or Negative Response (NR)	not profitable to apply nutrients

In a basic soil test, each nutrient is given a numerical value (usually recorded in ppm), a letter rating and a fertilizer recommendation for the crop specified on the soil test submission form (usually in lb/acre). The Ontario soil test nutrient ratings were revised, effective January 1, 2008, to reflect the likelihood of having a large enough response to applied fertilizer in the year of application to pay for the fertilizer and allow additional profit for the grower. The rating system is explained in Table 2-2, *Soil Test Nutrient Ratings*, this page. Soil tests taken prior to 2008 still reflect the old rating system. When using one of these older soil tests, select a fertilizer rate based on the numerical (ppm or mg/L) soil test value reported on the soil test.

A soil test recommendation is affected by manure application, plowing down of legume sod and the type of crop to be fertilized. This information is essential for a reliable fertilizer recommendation. Recommended fertilizer rates, especially for nitrogen and phosphorus should be adjusted if manure and cover crops are used.

There are several methods used in developing fertilizer recommendations from soil test results.

OMAFRA-Accredited Recommendations`

The OMAFRA-accredited program uses field trials to determine the maximum economic rate of each nutrient. This amount is most likely to maximize profit in the current year. Applying nutrients at the OMAFRA-recommended rate will maintain or gradually increase soil fertility. As a nutrient's soil test value increases, the economic return per unit of fertilizer decreases. The soil test ratings of low response (LR), rare response (RR) or no response (NR) indicate that an economic response to adding more of that nutrient is unlikely. For some crops, a specific nutrient may be recommended to enhance crop quality. Adding nutrients to soils with an NR rating may reduce crop yields or quality by interfering with the uptake of other nutrients.

Soil Tests From Other Laboratories

Each year, a number of farmers ask how to interpret results from laboratories that are not accredited. Provided the other laboratory uses the identical test used by the OMAFRA-accredited service and expresses its results in the same units, the OMAFRA fertilizer requirements for phosphate and potash can be determined. However, there is no assurance of the accuracy of the analysis.

Only OMAFRA-accredited soil tests can be relied on to provide accurate fertilizer recommendations. Be certain that the service you are using is accredited. To be accredited, a laboratory must use OMAFRA-approved testing procedures, must demonstrate acceptable analytical precision and accuracy and must provide the OMAFRA fertilizer recommendations. Soil tests on farms that must complete a nutrient management plan must be carried out at OMAFRA-accredited labs.

Other Recommendation Systems

Crop Removal Recommendations

The crop removal system selects fertilizer rates to replace the nutrients removed in the harvested portion of the crop. This system does not account for naturally occurring levels of nutrients supplied by the soil. As a result, the rates recommended for phosphorus and potassium are often uneconomical. On soils with a rating of low response (LR), rare response (RR) or no response (NR), the increase in yield may not pay for the additional fertilizer recommended through crop removal calculations. On soils with a high response rating, crop removal may result in an insufficient fertilizer application. Crop removal of phosphorus and potassium is not closely related to phosphorus and potassium fertilizer requirements.

Build-up and Maintenance Recommendations

Build-up and maintenance recommendations aim to meet the crop's annual nutrient requirement and to improve the soil-test value. For soils testing in the low response (LR) range or higher, additional fertilizer is recommended to maintain high soil test levels despite the low probability of an economical response. High levels of some nutrients may interfere with the uptake of others and cause yield reductions. There is no economic advantage to maintaining soil test levels in the rare response (RR) or no response (NR) range. Most crops can be grown on these soils for several years before fertilizer is required.

Base Saturation Ratio Recommendations

Some soil reports use base saturation ratios to develop recommendations for potassium, calcium and magnesium. This system is designed to result in ideal proportions of each nutrient in relation to the others. The ratios of these three nutrients are used as indicators of their availability. Crops can grow at a wide range of potassium:calcium:magnesium ratios. Crop response to these nutrients rarely occurs unless the soil test level indicates a deficiency. Many Ontario soils are naturally high in calcium and magnesium. As a result, the rates of potassium recommended in this system are often high and uneconomical. Striving to meet an exact ratio has little, if any, effect on crop yield.

Plant Analysis

Plant analysis measures the nutrient content of plant tissue. Comparing the results against the "normal" and "critical" values for the crop can indicate whether nutrient supply is adequate for optimum growth.

Plant analysis is the basis of fertilizer recommendations for tree fruits and grapes, and is a useful supplement to soil testing for evaluation of the fertility status of other crops. It is quite independent of soil testing and can provide a valuable "second opinion," especially for phosphorus, potassium, magnesium and manganese. It has not been very reliable for nitrogen and zinc. There is no reliable soil test for boron or copper, so plant analysis and visual symptoms are used for diagnosing deficiencies. The visual symptoms are particularly important for ginseng growers to recognize. Ginseng is sensitive to excess boron (Plate 22, page 92). Leaf analysis is the only way to confirm if ginseng has a boron deficiency or toxicity.

Plant analysis has limitations. Expert help in interpreting the results is often needed, since plant analysis does not necessarily indicate the cause of a deficiency or the amount of fertilizer required to correct it.

Sampling

Time of sampling has a major effect on the results since nutrient levels within a plant vary considerably with the age of the plant. Results are difficult to interpret if samples are taken at times other than those recommended. Nevertheless, sample plants suspected of being nutrient deficient as soon as a problem appears. Take samples from a problem area rather than from the entire field.

Take samples for plant analysis from at least 20 plants distributed throughout the area chosen for sampling. Each sample should consist of at least 100 g of fresh

material. Sample problem areas separately. When taking samples for plant analysis, take care not to contaminate the sample with soil. Even a small amount of soil will cause the results to be invalid, especially for micronutrients.

In ginseng, take samples after the plants reach full canopy, usually early to mid-July. Sampling during leaf expansion will produce variable and inaccurate results. Nutrient levels in ginseng leaves may be affected by flowering and seed development and by deflowering. If nutrient deficiencies or toxicities are suspected, take samples from good and bad areas in gardens at the same stage of development. Send leaf samples and soil samples to the lab together. Take the samples in the same areas at the same time.

Sample Preparation

Deliver samples of fresh plant material directly to the laboratory. If they cannot be delivered immediately, dry them to prevent spoilage. Samples may be dried in an oven at 65°C or less or dried in the sun, provided precautions are taken to prevent contamination with dust or soil. Avoid contact of samples with galvanized (zinc-coated) metal, brass or copper.

Soil Micronutrient Tests

OMAFRA-accredited tests are available for manganese and zinc. Zinc and manganese soil tests are best used in conjunction with visible deficiency symptoms. With manganese, plant analysis is also useful. OMAFRA-accredited tests are not available for boron, copper, iron or molybdenum. Plant analysis is generally a better indicator of deficiencies of these nutrients.

Contamination

Great care is required to prevent contamination of soil samples with micronutrients, particularly zinc. Do not use galvanized (zinc-plated) soil sampling tubes to take soil samples for micronutrient tests. Do not use metal containers to collect and mix samples. Clean, plastic containers in good condition should be satisfactory. Soil samples that have contacted galvanized surfaces are unsatisfactory for zinc soil tests. Be careful to keep extraneous dust out of the samples.

Soil Sampling

Micronutrient deficiencies frequently occur in small patches in fields. In these cases, analysis of soil or plant material taken from the entire field is unlikely to find the problem. Sample problem areas separately.

Plant analyses may be obtained from several laboratories in Ontario. See Appendix E, *Accredited Soil-Testing Laboratories in Ontario*, on page 84. Tissue analysis is not an OMAFRA-accredited test.

Fertilizer Recommendations

Soil Acidity and Liming

The pH scale ranging from 0 to 14 is used to indicate acidity and alkalinity. A pH value of 7.0 is neutral, values below 7.0 are acid, and those above 7.0 are alkaline. Most field crops grow well in a soil pH range from 6.0 to 8.0. Most ginseng gardens are adjusted to pH 6.5 before seeding. As the garden ages, the pH will drop slightly. When the pH is higher than 7.5, roots may be predisposed to disease.

To correct soil acidity, broadcast ground limestone and work it into the soil at rates determined by a soil test.

The Buffer pH

Different soils with any one soil pH value, for example 5.2, will require different amounts of lime to bring the pH to a particular desired level, for example 6.0, depending chiefly on the clay and organic matter content of each soil. The soil pH is used to determine whether soils should be limed, but a separate soil test, the buffer pH, is run on soils needing lime to determine the amount of lime required. For soils needing lime (based on soil pH), use Table 2–3, *Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH*, opposite page, to determine the amount of lime required to reach different “target” soil pH values.

Limestone Quality

Calcitic limestone consists largely of calcium carbonate, and dolomitic limestone is a mixture of both calcium and magnesium carbonates. Use dolomitic limestone on soils with a magnesium soil test of 100 or less, as it is an excellent and inexpensive source of magnesium for acid soils. On soils with magnesium tests greater than 100, calcitic or dolomitic limestone may be used.

Two main factors affect the value of limestone for soil application. One of these is the amount of acid a given quantity of limestone will neutralize when it is totally dissolved. This is called the “neutralizing value” and is expressed as a percentage of the neutralizing value of pure calcium carbonate. A limestone that will neutralize 90% as much acid as pure calcium carbonate is said to have a neutralizing value of 90. In general, the higher the calcium and magnesium content of a limestone, the higher the neutralizing value.

Table 2-3. Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH

Ground limestone required in tonne/ha
(Based on an Agricultural Index of 75)

Buffer pH	Target soil pH = 6.5 (Lime if soil pH below 6.1)	Target soil pH = 6.0 (Lime if soil pH below 5.6)	Target soil pH = 5.5 (Lime if soil pH below 5.1)
7.0	2	1	1
6.9	2	1	1
6.8	2	1	1
6.7	2	2	1
6.6	3	2	1
6.5	3	2	1
6.4	4	3	2
6.3	5	3	2
6.2	6	4	2
6.1	7	5	2
6.0	9	6	3
5.9	10	7	4
5.8	12	8	4
5.7	13	8	5
5.6	15	11	6
5.5	17	12	8
5.4	19	14	9
5.3	20	15	10
5.2	20	17	11
5.1	20	19	13
5.0	20	20	15
4.9	20	20	16
4.8	20	20	18
4.7	20	20	20
4.6	20	20	20

The second factor that affects the value of limestone as a neutralizer of acidity is the particle size. Limestone rock has much less surface area to react with soil than finely powdered limestone and, hence, neutralizes acidity much more slowly — so slowly that it is of little value. The calculation of a fineness rating for ground limestone is illustrated in Table 2-4, *Example Calculation of the Fineness Rating of a Limestone*, this page.

Table 2-4. Example Calculation of the Fineness Rating of a Limestone

Particle Size	% of Sample	Effectiveness x Factor	Fineness = Rating
Coarser than #10 sieve ¹	10	x 0	= 0
#10 to #60 sieve	40	x 0.4	= 16
Finer than #60 sieve	50	x 1.0	= 50
Fineness Rating of Whole Sample			66

¹ A #10 Tyler sieve has wires spaced 2.0 mm apart.

The Agricultural Index

Some means of combining the Neutralizing Value and the Fineness Rating is needed to compare various limestones that are available. The index that has been developed in Ontario to do this is called the "Agricultural Index."

$$\text{The Agricultural Index} = \frac{\text{neutralizing value} \times \text{fineness rating}}{100}$$

The Agricultural Index can be used to compare the relative value of different limestones for neutralization of soil acidity. Lime with a high Agricultural Index is worth proportionately more than lime with a low Index because it may be applied at a lower rate and still have the same impact. If two ground limestones, A and B, have Agricultural Indices of 50 and 80 respectively, the rate of application of limestone A required for a particular soil will be $80/50 \times$ the rate required for limestone B. Limestone A spread on your farm is worth $50/80 \times$ the price of limestone B per tonne.

Recommendations are based on limestone with an Agricultural Index of 75. If you know the Agricultural Index of the limestone to be used, you can calculate a rate of application specifically for limestone of that quality. Use the following equation:

$$\text{Limestone application rate from soil test} \times \frac{75}{\text{Agricultural Index of your limestone}} = \text{Rate of application of your limestone}$$

For example, if the limestone requirement as determined by a soil test is 9 t/ha and the most suitable source of limestone from a quality and price standpoint has an Agricultural Index of 90, apply $75/90 \times 9 = 7.5$ t/ha.

The Agricultural Index does not provide information about magnesium content. Use dolomitic limestone on soils low in magnesium.

Tillage Depth

Lime recommendations presented here should raise the pH of the top 15 cm of a soil to the listed target pH. If the soil is tilled to a lesser or greater depth than 15 cm, proportionately less or more lime is required to reach the same target pH. Where reduced tillage depths are used, reduce the rates of application proportionately. More frequent liming will be needed.

Lowering Soil pH

On soils with pH values below 6.5, it is possible to lower the pH (make the soil more acid) by adding sulphur or ammonium sulphate. This may be desirable for some crops, for example, for scab control where potatoes are being grown. It is not required for ginseng where the desired pH is 6.5. Soil pH cannot be made to flip-flop from a low pH to a more moderate pH from year to year. If the soil pH is above 6.5, it is usually quite impractical to lower it because of the very large amounts of sulphur or ammonium sulphate required.

Nitrogen

The recommended nitrogen requirement for ginseng is 40 kg N/ha applied every year of production as a broadcast application in the spring prior to emergence. Nitrogen rates exceeding 50 kg N/ha do not increase root yield and may lead to a reduction in yield. The rate of nitrogen applied has little effect on the root ginsenoside concentration. Research has shown that nitrogen requirements for fertigation are similar to broadcast application.

Phosphate and Potash

Phosphate and potash recommendations are based on OMAFRA-accredited soil tests (see Table 2-5, *Phosphorus Requirements for Ginseng on Mineral Soils*, this page, and Table 2-6, *Potassium Requirements for Ginseng on Mineral Soils*, opposite page). Use these tables only with OMAFRA-accredited soil tests.

Table 2-5. Phosphorus Requirements for Ginseng on Mineral Soils

Soil phosphorus (P) (0.5 M sodium bicarbonate) mg P/L of soil (ppm P)	Phosphate (P_2O_5) Required kg/ha	
	new gardens	established gardens
0-3	270 HR ¹	80 HR
4-5	260 HR	60 HR
6-7	250 HR	50 HR
8-9	240 HR	40 HR
10-12	230 HR	30 MR
13-15	220 HR	20 MR
16-20	200 HR	0 LR
21-25	170 HR	0 LR
26-30	140 MR	0 RR
31-40	110 MR	0 RR
41-50	80 MR	0 RR
51-60	50 LR	0 RR
61-80	0 RR	0 NR
80 +	0 RR	0 NR

¹ HR = High Response, MR = Medium Response,
LR = Low Response, RR = Rare Response,
NR = No Response.

Where a soil test is not available, a rough estimate of requirements can be obtained from these tables using the following guidelines:

- Where the field has been fertilized regularly for a number of years or heavily in recent years, use one of the rates of phosphate and potash recommended for the Medium Response (MR) soil test rating.
- If the field has received little fertilizer in the past, use one of the rates recommended for a High Response (HR) soil test rating.

Soils rated No Response (NR) for phosphorus contain much more plant-available phosphorus than required for most crops. Avoid applications of phosphorous fertilizers, compost, manure, sewage sludge or other sources of phosphorus to these soils because of the increased risk of water pollution.

Some clay and clay loam soils are naturally high in potassium and do not require any potash fertilizers. Only a soil test can adequately determine potash requirements.

Table 2-6. Potassium Requirements for Ginseng on Mineral Soils

Soil potassium (K) (normal ammonium acetate) mg K/L of soil (ppm K)	Potash (K ₂ O) Required kg/ha
0-15	230 HR
16-30	220 HR
31-45	200 HR
46-60	180 HR
61-80	140 HR
81-100	100 HR
101-129	70 MR
121-150	50 MR
151-180	40 MR
181-210	0 LR
211-250	0 RR
250 +	0 NR

Magnesium

Magnesium is a plant nutrient that is naturally plentiful in many Ontario soils. Soils with magnesium soil tests below 20 (OMAFRA soil test) require magnesium application for the production of most crops. Very few Ontario soils have magnesium tests below 20. If the soil pH is below 6.0, the most effective and inexpensive means of supplying magnesium is by the application of dolomitic lime. If the pH is above 6.0, and the soil test 20 or below, magnesium can be supplied through either magnesium sulphate or sulphate of potash magnesia, which is a mixture of sulphate of potash and magnesium sulphate. Apply 30 kg/ha of actual soluble magnesium. These latter sources of magnesium are usually much more expensive than magnesium from dolomitic limestone.

Potassium competes with magnesium for uptake by crops, and excessive potash applications can therefore induce or increase magnesium deficiency. For this reason, it is important to monitor soil potassium levels and to carefully control potash fertilizer applications on low-magnesium soils.

Calcium

Calcium deficiency has not been a problem in Ontario soils with soil pH adequate for crop growth. Adequate soil pH is a reliable indicator of adequate calcium in the soil.

Table 2-7. Manganese Availability Index Interpretation

Manganese Index	Suggested Treatments
>30	Soil manganese availability is adequate for field-grown crops.
16-30	Soil manganese availability is adequate for many crops but is approaching deficiency levels for some crops. If deficiency symptoms appear, spray with manganese. Consider a re-check for deficiency using plant analysis.
<16	Soil manganese availability is believed to be insufficient for many crops. Spray with manganese if deficiency symptoms appear.

Micronutrient Fertilizers

Do not combine micronutrient elements with insecticide or fungicide sprays unless the manufacturer's directions indicate that this may be done or experience has shown that they are compatible.

Apply micronutrient elements only on competent advice or where experience has proven their application to be necessary. Soil or foliar applications can be made. Soil applications are generally made at soil-preparation time, and foliar applications are applied during the growing season. Include a sticker-spreader in micronutrient sprays.

Preventing and Correcting Manganese Deficiency

Manganese is less available at high soil pH, so it is important not to add more lime than is needed to correct soil acidity. The OMAFRA accredited soil manganese test is reported as a Manganese Availability Index. This index reflects the effect of the soil's pH on manganese availability. Interpretation of the Manganese Availability Index is found in Table 2-7, *Manganese Availability Index Interpretation*, this page.

Preventing and Correcting Zinc Deficiency

High phosphorus in the soil and/or in the fertilizer can cause or increase the severity of zinc deficiency. Apply only the recommended amount of phosphorus. Use of animal manures can prevent or reduce zinc deficiency. Erosion control can prevent deficiency of zinc by maintaining the topsoil. The OMAFRA accredited soil zinc test is reported as a Zinc Availability Index. This index reflects the effect of the soil's pH on zinc availability. Interpretation of the Zinc Availability Index is found in Table 2-8, *Zinc Availability Index Interpretation*, next page.

Table 2-8. Zinc Availability Index Interpretation

Zinc Availability Index	Suggested Treatments
>200	Suspect contamination of the sample or of the field.
25–200	Soil zinc availability is adequate for most field-grown crops.
15–24	Zinc availability is adequate for most crops but is bordering on deficiency for some. If the field sampled is uneven in soil texture, pH or erosion, some areas may respond to zinc applications.
<15	Zinc is likely to be deficient for some crops and should be applied in the fertilizer.

Zinc deficiency can be prevented by application of zinc fertilizer to the soil. Foliar sprays can be useful for correcting a deficiency after the symptoms have appeared, provided this is done early in the growing season.

Copper

Copper soil tests are quite unreliable on Ontario soils, but plant analysis is useful.

Copper is unlikely to be deficient in mineral soil, except perhaps in very sandy soils. Copper deficiency does occur in organic soils and is best diagnosed by plant analysis. When organic soils are first brought into cultivation, apply copper to the soil at 14 kg/ha for each of the first 3 years.

Boron

Boron is required on some soils. When boron deficiency occurs, it is usually associated with dry weather. Thus it has not been possible to develop a reliable soil test. Plant analysis is useful as a predictor of boron requirements, as are visible symptoms on the plants. See *Site Preparation*, on page 32.

Because boron is needed only in very small quantities, and since an overdose is toxic, take extreme care in its use. Boron toxicity in ginseng is discussed in *Abiotic Disorders of Ginseng*, on page 72. Do not band boron. Boron deficiency has been suggested as one of the causes of rusty root in ginseng but this has not been confirmed by scientific evaluation.

Iron and Molybdenum

Iron and molybdenum have not been found to be deficient in field crops in Ontario.

Table 2-9. Adjustment of Nitrogen Requirement Where Crops Containing Legumes Are Plowed Down

Type of Crop	For All Crops, Deduct From N Requirement kg N/ha
Less than ½ legume	0
½ to ½ legume	55
½ or more legume	100
Perennial legumes seeded and plowed in the same year	45 ¹
Soybean and field bean residue	0

¹ Applies where the legume stand is thick and over 40 cm high.

Adjustments to Fertilizer Recommendations

Adjustment for Legumes Plowed Down

When sod containing perennial legumes such as alfalfa, trefoil and clover are plowed under, they supply an appreciable amount of nitrogen to the following crop.

Table 2-9, *Adjustment of Nitrogen Requirement Where Crops Containing Legumes Are Plowed Down*, this page, shows reductions that should be made in nitrogen fertilizer applications to crops following sod containing legumes.

Manure

A large number of Ontario farms produce livestock, generating over 33 million tonnes of manure. Proper management of the nutrients from manure is essential for optimum economic benefit to the farmer with minimal impact on the environment. See Table 2-10, *Available Nutrients and Value for Manure From Various Livestock Types – Solid Manure*, opposite page.

In ginseng, apply manure no later than 4–6 weeks prior to fumigation. Ginseng growers commonly apply 22–89 tonnes of composted cattle manure per hectare (10–40 tons/acre). After application, work manure thoroughly into the soil. Composted turkey manure is also used but at lower rates.

Manure Analysis

Manure analysis is necessary because the quantities of nutrients contained in manure vary from farm to farm, especially the phosphorus and potash components. Type of livestock, ration, bedding, added liquids and storage system all affect the nutrient content.

Table 2-10. Available Nutrients and Value for Manure From Various Livestock Types – Solid Manure

The values in these tables were compiled by OMAFRA, with aggregate sample data provided by A&L Labs, Agri-Food Labs, Stratford Agri-Analysis and the University of Guelph Analytical Lab, and summarize the information found in the NMAN software.

Animal Type		Available Nutrients (in year of application)				Value		Total Nutrient Content (as-is basis)					# Samples
		Aver DM	Usable N ¹	P ₂ O ₅	K ₂ O	Year 1 value ²	Year 2-4 value	Total N	NH ₄ -N	P	K		
		%	kg/tonne			\$/tonne		%	mg/L	%	%	%	
Hog	average	30.2	4.0	4.3	6.0	21.70	10.90	0.90	2,702	0.27	0.46	0.56	61
Dairy	average	25.0	1.8	1.5	5.3	11.70	4.50	0.59	1,221	0.12	0.17	0.49	174
	30% +	38.9	1.6	1.6	5.7	11.95	4.80	0.65	796	0.08	0.17	0.53	36
	18%-30%	21.3	1.9	1.5	5.1	11.60	4.40	0.57	1,331	0.13	0.16	0.48	138
Beef	average	28.4	1.9	2.2	6.1	14.15	6.30	0.74	1,028	0.10	0.24	0.57	184
	30% +	38.1	2.1	3.5	7.9	19.40	9.70	0.95	951	0.10	0.38	0.74	62
	18%-30%	23.5	1.7	1.5	5.2	11.50	4.60	0.63	1,067	0.11	0.16	0.48	122
Sheep	average	33.8	2.9	2.6	8.4	19.10	7.10	0.80	2,299	0.23	0.28	0.78	57
Dairy goats	average	35.2	3.8	2.6	11.1	23.30	7.60	1.07	2,865	0.29	0.28	1.03	41
Composted cattle		38.3	1.7	2.6	11.9	11.90	21.15	0.86	543	0.05	0.28	1.10	29
Compost: all types		38.9	2.0	4.1	8.9	8.90	21.75	0.84	1,035	0.10	0.45	0.82	63
Grain-fed veal	average	28.8	2.2	1.7	5.1	12.40	5.30	0.79	1,328	0.13	0.18	0.47	18
Horses	average	37.4	1.3	1.4	4.6	10.10	4.10	0.50	749	0.07	0.15	0.43	41
	>50%	63.0	0.9	1.9	9.6	16.05	6.05	0.80	591	0.06	0.21	0.89	4
	<50%	34.6	1.3	1.3	4.1	9.30	3.90	0.47	769	0.08	0.15	0.38	37
Poultry	average	55.3	10.6	11.0	13.4	54.10	28.95	2.45	5,339	0.53	1.20	1.24	809
	80% +	85.1	11.4	15.5	18.8	71.10	41.90	3.36	2,129	0.21	1.69	1.74	59
	60%-80%	71.0	11.9	13.0	16.7	64.00	34.65	3.00	4,868	0.49	1.41	1.55	358
	40%-60%	50.0	9.8	11.4	13.4	53.90	29.30	2.25	5,144	0.51	1.24	1.24	146
	18%-40%	28.5	8.8	6.8	7.1	35.45	17.05	1.55	6,976	0.70	0.74	0.66	246
	layers	34.2	10.5	8.2	8.7	42.45	20.70	1.93	7,810	0.78	0.89	0.80	161
	pullets	47.9	13.8	12.5	14.6	63.20	33.40	3.14	7,236	0.72	1.36	1.35	50
	broilers	68.5	11.9	12.2	16.4	62.00	33.40	3.09	4,364	0.44	1.33	1.52	48
	broiler breeder growers	63.6	7.5	13.1	14.1	55.10	32.70	1.92	2,965	0.30	1.42	1.31	24
	broiler breeder layers	65.1	8.5	14.5	16.8	62.70	36.60	2.21	3,175	0.32	1.58	1.56	74
Turkeys		50.6	13.0	12.9	15.7	64.20	33.00	2.74	8,038	0.80	1.40	1.45	61
Biosolids	dewatered	32.1	13.3	12.1	1.2	46.90	34.80	3.76	3,443	0.34	1.31	0.11	89

¹ Useable N = amount of nitrogen available in the year of application assuming spring application incorporated within 24 hr.

A simplified useable N for fall-applied manure = [(% total N x 0.5) x 10] for solid manure.

² Value of manure is based on purchase price of an equivalent amount of mineral fertilizer:

(N - P₂O₅ - K₂O = 1.43 - 2.20 - 1.10 \$/kg). The actual immediate value for crop production will be less if all the nutrients applied are not required for growing the crop. The manure value is based on the purchase price of an equivalent amount of mineral fertilizer (Jun 08). The micronutrient and organic matter values are not reflected in these tables.

Table 2-11. Approximate Ammonium-Nitrogen Levels Available by Livestock Type
(expressed as % of total manure N)

Manure Type	Ammonium-N
Liquid poultry	75%
Liquid hog	62%
Liquid beef	60%
Liquid dairy	50%
Biosolids (sewage sludge)	27%
Solid hog	30%
Solid poultry	30%
Solid dairy	25%
Solid beef	12%

Table 2-12. Estimated Percentage of Ammonium-Nitrogen Lost Due to Weather and Soil Conditions

	Cool (<10°C)		Warm (>25°C)	
	wet	dry	wet	dry
Incorporated				
Injected in season	0	0	0	0
Incorporated within 1 day	10	15	25	50
Incorporated within 2 days	13	19	31	57
Incorporated within 3 days	15	22	38	65
Incorporated within 4 days	17	26	44	73
Incorporated within 5 days	20	30	50	80
Not incorporated				
Spring/summer/early fall:				
Bare soil	40	50	75	90
Crop residue	30	35	60	70
Standing crop	20	25	40	50
Late Fall (air temp <10°C)	25	25	N/A	N/A

adapted: Beauchamp, 1995

There are two nitrogen components in manure — ammonium-nitrogen and organic nitrogen. Ammonium-nitrogen makes up the largest percentage of the nitrogen in liquid manure, with approximate percentages listed by livestock type in Table 2-11, *Approximate Ammonium-Nitrogen Levels Available by Livestock Type*, this page. The organic nitrogen component is available over time as the organic matter breaks down. About 30% of the organic nitrogen component of manure is assumed to be available to a growing crop. The percentage is generally higher in poultry and lower for ruminant manure.

Ammonium-nitrogen is immediately available to a growing crop but is also most easily lost to volatilization unless incorporated soon after application. Soil moisture and weather conditions will determine how quickly and how much loss to expect. These losses are highest during sunny, high-temperature days when soils are dry; losses are lowest when conditions are overcast and cold, and soils are moist, or during rainy periods. Table 2-12, *Estimated Percentage of Ammonium-Nitrogen Lost Due to Weather and Soil Conditions*, this page, gives estimated losses due to weather and soil conditions.

Long-Term Value of Manure

The long-term availability of phosphorus (P), potassium (K), magnesium, zinc or manganese from previous manure applications is best estimated by soil testing. Application of large quantities of manure over time can result in high levels of available P and K in soils. Manures also contribute other plant nutrients and organic matter to soil that may be of some long-term value.

Most of the available nitrogen in manures is used by the crop or is lost during the first growing season following application. The remaining organic nitrogen becomes available in small, diminishing quantities in the succeeding years. Generally, the amount of residual nitrogen from a single application is too small to make

a practical difference in nitrogen recommendations for a crop. However, where solid manure is applied regularly to the same field, there can be significant residual nitrogen available for a crop. The N soil test for corn or barley can be used to assess available nitrogen in succeeding years following application. Use the soil test for P and K to measure residual phosphorus and potassium from manure applications.

Crop Requirements

When determining additional nitrogen needs from manure or fertilizer, take into account residual nitrogen from legume crops (see Table 2-9, *Adjustment of Nitrogen Requirement Where Crops Containing Legumes Are Plowed Down*, on page 14).

Calibrating Spreaders

Calibrating manure application equipment is important. Several methods can be used to measure spreading rates. Weighing a load of manure and measuring the area that load covers is one method of estimating the rate. Solid manure can be weighed by placing plastic sheets on the ground and liquid manure by using straight-walled pails for measuring depth of application. Consider overlap, especially in irrigation systems. Table 2-13, *Calibrating Manure Spreaders*, opposite page, gives an estimate of application rates, while Table 2-14, *Densities of Different Types of Manure*, opposite page, distinguishes between the densities of different types of manure. For further detail, see the OMAFRA website at www.ontario.ca/crops.

Table 2-13. Calibrating Manure Spreaders

Solid Manure Calibration ¹		Liquid Manure Calibration ²					
kg of Manure (per sheet)	Application Rate t/ha ³	Depth of Manure in Pail		Application Rate			
		in.	mm	L/ha	Imp.	U.S.	
					gal/acre		
0.5	3.6	1/8	2.5	25,000	2,225	2,675	
0.9	7.2	1/8	3.2	32,000	2,850	3,420	
1.4	10.8	1/4	6.4	64,000	5,520	6,845	
1.8	14.3	3/8	10	100,000	8,900	10,690	
2.3	17.9	1/2	12.7	127,000	11,305	13,580	
3.2	25.1	3/4	15.0	150,000	13,355	16,040	
4.5	35.8	3/4	19.1	191,000	17,000	20,420	
6.8	53.8	1	25.4	254,000	22,610	27,160	

¹ Using a 122-cm-x-102-cm sheet (40-in.-x-48-in. plastic feedbag).

² Using a straight-walled pail.

³ Tons per acre = tonnes per hectare x 0.45.

Environmental Concerns With Manure

The use and storage of manure and nutrients is regulated in Ontario under the *Nutrient Management Act, 2002*. Follow the guidelines for the temporary storage of manure found in the OMAFRA Factsheet *Temporary Field Storage of Solid Manure or Prescribed Materials*, Order No. 05-009, to minimize environmental impact. For more information on the *Nutrient Management Act*, see the OMAFRA website at www.ontario.ca/NMA.

Spreading manure in the winter and early spring is not recommended because of the potential for runoff to surface water. The fate of the first meltwater following manure application determines whether this will be a problem or not. Do not incorporate this practice into a nutrient management plan. In years when winter spreading may be necessary, take care to select fields where there is no risk of runoff to surface water.

Rain can cause organic nitrogen to wash into streams if manure has been applied to unprotected cropland. Phosphorus attached to soil particles can be carried to streams by soil erosion. Conservation practices can reduce the amount of nutrients polluting waterways.

Do not apply manure near watercourses. Runoff potential is influenced by field slope and soil texture. Use Table 2-15, *Determining Minimum Separation Distance From Watercourses*, this page, to determine the runoff potential to establish a safe minimum separation distance. In a no-till system that includes a 3-m-wide buffer strip along the watercourse, the separation distance can be reduced to 9 m for liquid manure and 4.5 m for solid manure.

Table 2-14. Densities of Different Types of Manure

Manure Type	Weight per			
	Cubic Metre	Cubic Foot	Litre	Bushel
Liquid	1,000 kg	62 lb	1.0 kg	80 lb
Semi-solid	960 kg	60 lb	0.9 kg	76 lb
Thick solid	800 kg	50 lb	0.8 kg	64 lb
Light solid	560 kg	35 lb	0.6 kg	45 lb
Dry poultry litter	400 kg	25 lb	0.4 kg	30 lb

1 bushel = 1.25 cubic feet

Water flowing in tile drains can become contaminated if manure enters a catchbasin or travels through soil cracks to the tiles. Maintain a 9-m buffer around a catchbasin or surface inlet when spreading liquid manure (4.5 m for solid manure). If there is any history of tile contamination via soil cracks or macropores, till prior to application.

Applications of nutrients in manure or fertilizer in excess of crop requirements can result in contamination of groundwater, particularly on shallow soils over bedrock, soils with a water table close to the surface or very sandy soils where leaching is a concern. Groundwater contamination can occur by mass flow through cracks and holes to groundwater or through leaching of nitrates through the soil.

Table 2-15. Determining Minimum Separation Distance From Watercourses

Soil Texture	Runoff Potential			
	Field Slope Within 150 m of Watercourse			
	<0.5%	0.5%–2%	2%–5%	>5%
Sand	Very low	Very low	Very low	Low
Loam	Very low	Low	Low	Moderate
Clay loam	Low	Moderate	Moderate	High
Clay	Moderate	High	High	High

Use the runoff potential to determine the minimum separation distance.

Runoff Potential	Minimum Separation Distance			
	Surface Applied		Incorporated or Pre-Tilled	
	Liquid	Solid	Liquid	Solid
High	30 m	15 m	18 m	9 m
Moderate	23 m	11 m	14 m	7 m
Low	15 m	8 m	9 m	4.5 m
Very Low	9 m	4.5 m	9 m	4.5 m

Nutrient Management Practices BMP

Fertilizer Materials

Most nutrients needed for plant growth can be supplied by several fertilizer materials. See Table 2-16, *Fertilizer Materials — Primary Nutrients*, this page, and Table 2-17, *Fertilizer Materials — Secondary and Micronutrients*, opposite page.

Soluble Salts in Farm Soils

High concentrations of water-soluble salts in soils can prevent or delay germination of seeds and can kill established plants or seriously retard their growth.

Ontario soils are naturally low in soluble salts. They therefore rarely cause a problem in crop production and are not routinely measured in soil tests.

Soluble salts in soils can result from excessive applications of fertilizers and manures, runoff of salts applied to roads and chemical spills on farmland. High concentrations of soluble salts in or near a fertilizer band can cause serious early plant growth problems without seriously affecting the salt concentrations in the remainder of the soil.

A given amount of salt in a soil provides a higher salt concentration in soil water if the amount of water is small. Soluble salts also interfere with the uptake of water by plants. For these reasons, plant growth is most affected by soluble salts in periods of low moisture supply (drought periods).

Soluble salts can be measured readily in the laboratory by measuring the electrical conductivity of a soil-water slurry. The higher the concentration of water-soluble salts, the higher the conductivity. Table 2-18, *Soil Conductivity Reading Interpretation*, opposite page, provides an interpretation of soil conductivity reading as read in Ontario field soils in a 2:1 water:soil paste, the procedure used by the OMAFRA-accredited soil testing program.

Toxicity of Fertilizer Materials

All fertilizer salts are toxic to germinating seeds and to plant roots if applied in sufficient concentration near the seed.

Fertilizers vary in toxicity per unit of plant nutrient due to:

- differences in the amount of salts contained in the fertilizer per unit of plant nutrient
- differences in solubility of the salts in the soil
- the high toxicity of a few specific materials or elements (for example, ammonia and boron)

Table 2-16. Fertilizer Materials — Primary Nutrients

Nitrogen Materials	Form	% Nitrogen (N)
Ammonium nitrate	Dry	30 to 34
Calcium ammonium nitrate	Dry	27
Urea	Dry	45 to 46
Ammonium sulphate	Dry	20
Aqua ammonia	Liquid ¹	20
Ammonium nitrate-urea	Liquid	28
Ammonium nitrate-urea	Liquid	32
Ammonia-ammonium nitrate-urea	Liquid ¹	41
Ammonia-ammonium nitrate	Liquid ¹	41
Anhydrous ammonia	Liquid ¹	82
Phosphate Materials	% Phosphate (P₂O₅)	
Single superphosphate	20	
Triple superphosphate	44 to 46	
Monoammonium phosphate	48 to 52	
Diammonium phosphate (18-46-0)	46	
Potash Materials	% Potash (K₂O)	
Muriate of potash	60 to 62	
Sulphate of potash	50	
Sulphate of potash magnesia (11% Mg)	22	
Potassium nitrate (13-0-44)	44	

¹ Liquid under pressure.

Nitrogen Fertilizers

Ammonium nitrate, monoammonium phosphate and ammonium sulphate are similar in toxicity and are much safer than anhydrous ammonia, aqua ammonia or urea. Diammonium phosphate is more toxic than monoammonium phosphate but less toxic than urea. Take more care, particularly with sensitive seeds and on coarse-textured soil (sand and sandy loam), than is required with ammonium nitrate or monoammonium phosphate.

Because anhydrous ammonia and aqua ammonia are extremely toxic fertilizers, do not place them near seeds. It is preferable to make preplant applications crossways (perpendicular) to the direction in which the crop will be planted.

Urea is toxic when banded with or near the seed but is safe when broadcast at rates normally used. Fertilizers containing more than half as much nitrogen as phosphate frequently contain urea.

Table 2-17. Fertilizer Materials — Secondary and Micronutrients

Magnesium (Mg)	
Dolomitic limestone	6–13% Mg
Epsom salts (magnesium sulphate)	10.5% Mg
Sulphate of potash magnesia	11% Mg
Boron (B)	
Sodium borate	12–21% B
Solubor	20.5% B
Copper (Cu)	
Copper sulphate	13–25% Cu
Copper chelates	5–13% Cu
Manganese (Mn)	
Manganese sulphate	26–28% Mn
Molybdenum (Mo)	
Sodium molybdate	39% Mo
Zinc (Zn)	
Zinc sulphate	36% Zn
Zinc chelates	7–14% Zn
Zinc oxysulfate	18–36% Zn

Phosphate Fertilizers

Phosphate fertilizers are usually low in toxicity because a large portion of the phosphate is precipitated in the soil before it can reach the plant roots. The concentration of phosphorus in soil solution at any one time is very low. No limit is normally set for the safe rate at which phosphates may be applied with, or near, the seed of field-grown crops.

Diammonium phosphate is more toxic than other phosphate fertilizers (see Nitrogen Fertilizers, previous page).

Potash Fertilizers

Muriate of potash (KCl) is the most common source of potassium in fertilizers. It is less toxic per unit of plant nutrients than most nitrogen fertilizers. Sulphate of potash (K_2SO_4) is less toxic than muriate of potash. Sulphate of potash-magnesia has approximately the same toxicity per unit of potassium as muriate of potash. Potassium nitrate is one of the least toxic sources of potassium.

Fertilizers Containing Micronutrients

As fertilizers containing micronutrients (boron, copper, iron, manganese or zinc) are more toxic than the same materials without micronutrients, reduce rates to avoid plant injury. Do not band boron, as it is particularly toxic.

Table 2-18. Soil Conductivity Reading Interpretation

Conductivity "salt" reading millisiemens/cm	Rating	Plant Response
0–0.25	LOW	Suitable for most plants if recommended amounts of fertilizer are used.
0.26–0.45	MEDIUM	
0.46–0.70	HIGH	May reduce emergence and cause slight-to-severe damage to salt-sensitive plants.
0.71–1.00	EXCESSIVE	May prevent emergence and cause slight-to-severe damage to most plants.
1.00	EXCESSIVE	Expected to cause severe damage to most plants.

Foliar Fertilizers

Micronutrients can be supplied to the crop through foliar fertilization, particularly in instances where a deficiency is due to binding of these nutrients in the soil (i.e., manganese). Quantities of nutrients that can be applied this way are limited because of the danger of injuring the leaves. Take care when combining nutrients, that the resulting solution is not too concentrated. Check pesticide labels before mixing foliar nutrients with any pesticide spray. Foliar nutrients containing cytokinins can be toxic to ginseng if applied during canopy development. Cytokinins can interfere with elongation of stems and leaf veins, and application when the leaves are unfolding may result in leaf deformities that reduce the photosynthetic capacity of the plant.

Managing Soil Organic Matter

Soil organic matter helps maintain soil structure, enhances soil moisture-holding capacity, increases the soil's ability to hold nutrients and improves drainage. Maintaining adequate soil organic matter levels can help maintain crop yields, particularly in years of adverse weather.

Increasing soil organic matter is a slow process, since only a small part of the organic matter added to the soil ends up as stable humus. It is therefore important to keep as much organic matter in the soil as possible

Table 2–19. Matching Cover Crop Choices to Function

Cover Crop Function	Best Choices for Cover Crops
Nitrogen production	Legumes – red clover, peas, vetch
Nitrogen scavenging	Fall uptake – oilseed radish and other brassicas, oats Winter/spring uptake – rye, winter wheat
Weed suppression	Fast growing/shading plants – oilseed radish and other brassicas, winter rye, buckwheat
Nematode suppression ¹	Cutlass mustard, sudans/sorghums (Sordan 79, Trudan 8), pearl millet (CFPM 101), marigold (Crackerjack, Creole), oilseed radish (Adagio, Colonel)
Soil structure building	Grasses, i.e., oats, barley, rye, wheat, triticale, ryegrass, or fibrous root systems, i.e., red clover
Compaction reduction	Strong tap roots that grow over time – alfalfa, sweet clover
Biomass return to soil	Fall seeded – oats, oilseed radish Summer seeded – millets, sorghum, sudangrass, sorghum sudan
Erosion protection, i.e., wind, water	Winter rye, winter wheat, ryegrass (well established), spring cereals seeded early

¹ Not every cover crop has the ability to suppress nematode populations; some will even act as hosts. Cover crop activity is variety and nematode specific. In addition, to get the most activity, cover crops must be weed free and may require specific handling.

by reducing soil erosion and eliminating unnecessary tillage passes. Organic matter additions will also, over time, increase the total soil organic matter. These may be in the form of livestock manures, forage crops or cover crops. Manure is discussed in a previous section. Rotation plays a key role in maintaining soil organic matter. Try to rotate row crops over a period of 3–4 years with other crops that leave more residue prior to the preplant year for ginseng. Sometimes this is not realistic for a variety of reasons. Then it is very important to add organic matter through manure or compost additions and to take every opportunity to use green manure and cover crops to build and protect the soil.

Cover Crops

Planting cover crops is a common soil management practice for many Ontario farmers. There are a lot of good reasons for this practice but it is often hard to put a dollar value on the return from growing cover crops. Cover crops are an important part of a system of soil maintenance — particularly important on the lighter, lower organic-matter soils or fields with short rotations and little return of crop residue or manure. Know your goals when planting a cover crop and select the best one for that job. See Table 2–19, *Matching Cover Crop Choices to Function*, this page. Planted prior to ginseng planting, cover crops can improve soil structure, scavenge nutrients from applied manure and compost, and protect the soil from erosion.

Choosing a Cover Crop

There are often several different cover crop options for any one goal or function. Consider your farm's needs and management style to select the best cover crop for your farming system. See Table 2–20, *Choosing a Cover Crop*, opposite page.

Characteristics of Cover Crops

Information on the most commonly used cover crops is provided in Table 2–21, *Characteristics of Cover Crops Grown in Ontario*, on page 22.

Grass Crops

Grasses have fine, fibrous root systems that are well suited to holding soil in place and improving soil structure. Suitable grass species for cover crops are fast growing and relatively easy to kill, either chemically, mechanically or by winter weather. Grasses do not fix any nitrogen out of the atmosphere but can accumulate large quantities from the soil.

Spring Cereals

Spring cereals such as oats and barley are well suited for late summer and early fall plantings. Under good growing conditions, spring cereals will produce the greatest amount of crop biomass, making them valuable for building organic matter or providing ground cover. During the fall, these cereals will take up a greater amount of nitrogen than winter cereals such as rye. Once well established, spring cereals are relatively tolerant of frost, however, do not attempt to establish late in the fall, as the growth will be disappointing.

Table 2–20. Choosing a Cover Crop

Consideration	Comment
Growth habits	<ul style="list-style-type: none"> • What kind of growth habit is needed? • What type of growth is required, lots of vigorous late-fall growth or rapid early-spring growth? • Is deep rooting important?
Overwintering	<ul style="list-style-type: none"> • Does the cover crop need to survive overwinter? • Would it suit the cropping schedule and soil type if the cover crop winter killed and dried out by spring?
Control options	<ul style="list-style-type: none"> • Will the cover crop become a weed concern? • How is it controlled? • What options are there for control?
Sensitivity to herbicides	<ul style="list-style-type: none"> • How sensitive is the cover crop to herbicide residues from other crops in the rotation?
Seed cost and availability	<ul style="list-style-type: none"> • What is the seed cost and is the seed available in your area?
Establishment	<ul style="list-style-type: none"> • What is the best way to plant the seed? • Is different equipment required? • How easy is it to establish? • Will it create a solid cover? • Good establishment is critical to the success of the cover crop.
Nutrient management	<ul style="list-style-type: none"> • Is it a nitrogen producer or does the cover crop require nitrogen to grow well? • Does it scavenge well for nitrogen?
Pest management	<ul style="list-style-type: none"> • What crop family is the cover crop in? • Is it related to other crops in the rotation? • Could any pests develop on the cover crop and spread to a related crop in the rotation? • Are there pests that can be suppressed by the cover crop?

Winter Cereals

Winter cereals are highly versatile cover crops. They can be planted in summer and will tiller and thicken due to their need for vernalization or a cold treatment before reproduction. They can be planted in fall for soil cover. Winter cereals will generally overwinter well, providing winter and spring erosion protection. These grasses can be used to create spring wind barriers, residue mulch or killed early to minimize residue cover at planting.

Warm-Season Grasses

Warm season grasses such as sorghum and millet are best suited for planting into the warmer soils of late June, July and early August. They are very sensitive to frost. Root growth is extensive and the top growth lush. Be prepared to mow these grasses to keep stalks tender and prevent heading out. Do not mow closer than 15 cm to ensure regrowth. Some nitrogen may have to be applied to achieve optimal growth.

Legume Broadleaf Crops

Legume cover crops can fix nitrogen from the air, supplying nitrogen to the succeeding crop. Legumes will take up residual soil nitrogen or nitrogen from manure applications. They are approximately 80% as effective as non-legumes in nitrogen uptake from soil. Legumes also protect the soil from erosion and add organic matter. The amount of nitrogen fixed varies between species, although generally, more top growth equals more nitrogen fixed. Some legume species such as alfalfa and sweet clover have aggressive tap roots

that can break up subsoil compaction, but this requires more than one year's growth.

Examples of legume cover crops are hairy vetch, red clover, sweet clover, soybeans and field peas. There is some evidence that clovers will build up populations of *Cylindrocarpus* in the soil. *Cylindrocarpus* does not act as a pathogen on clovers. Soybeans may increase *Rhizoctonia* populations in the soil. See *Cylindrocarpus Diseases of Ginseng*, on page 58, and *Rhizoctonia Diseases of Ginseng*, on page 50.

Non-Legume Broadleaf Crops

These broadleaf crops cannot fix nitrogen out of the air but may absorb large quantities from the soil. Most of these crops are not winter-hardy, so additional control measures are not normally required. Do not allow them to go to seed, as the volunteer seed can become a significant weed problem.

New and Emerging Cover Crops

Every year there are new crops tried as cover crops. Often these species are from different parts of the globe and may not be well adapted to Ontario growing conditions. For more information on new and well-known cover crop species, see the OMAFRA website at www.ontario.ca/crops or see the regional pages from the Midwest Cover Crop Council at www.mccc.msu.edu/.

Table 2-21. Characteristics of Cover Crops Grown in Ontario

Species	Seeding Rate kg/ha ¹	Normal Seeding Time	Min. Germination Temp. C	Nitrogen Fixed (F) or Scavenged (S) ²	Overwintering Characteristics	Building Soil Structure	Weed Suppression	Quick Growth	Root Type
Grasses									
Spring cereals	100-125	Mid-Aug-Sept.	9	S	Killed by heavy frost	good	good	very fast	fibrous
Winter wheat	100-130	Sept-Oct	3	S	Overwinters very well	good	good	fast	fibrous
Winter rye	100-125	Sept-Oct	1	S	Overwinters very well	very good	very good	very fast	fibrous
Sorghum sudan	50	June-Aug	18	S	Killed by frost	good	good/fair	very fast	coarse fibrous
Pearl millet	4	June-Aug	18	S	Killed by frost	good	good/fair	fast	coarse fibrous
Ryegrass	12-18	April-May or Aug-early Sept	4.5	S	Annual, Italian partially survive; perennial overwinters	very good	fair/poor	slow establishment	fibrous
Broadleaves - Legumes									
Hairy vetch	20-30	Aug	15.6	F/S	Overwinters	good	fair/poor	slow establishment	tap with secondary fibrous
Red clover	8-10	March-April	5	F/S	Overwinters	good	fair	slow establishment	weak tap/fibrous
Sweet clover	8-10	March-April	5.5	F/S	Overwinters	good	fair	slow establishment	strong tap
Soybeans	40-50	Aug		F/S	Killed by frost	poor	good/fair	fast	tap
Field peas		Aug	5	F/S	Killed by heavy frost	poor	good/fair	fast	weak tap/fibrous
Broadleaves - Non-Legume									
Buckwheat	50-60	June through Aug	10	S	Killed by first frost	poor	very good	fast	weak tap/fibrous
Oilseed radish	10-14	Mid-Aug-early Sept	7	S	Killed by heavy frost	fair	very good	fast	moderate tap
Other brassicas, i.e., forage radish 0 = some cultivars are non-hosts	Varies with species	Mid-Aug-early Sept	5-7	S	Species dependent, many killed by heavy frost	fair	very good	fast	moderate tap

¹ 100 kg/ha = 90 lb/acre

² Oilseed radish, buckwheat and the grasses do not fix nitrogen from the air but are scavengers of nitrogen from soil and manure applications.

3. Growing Ginseng

This publication is designed to assist both the new and experienced ginseng grower. It discusses the history of the crop, its chemistry, its commercialization and the present state of the industry. The general chapters on pesticide use and soil fertility that appear at the beginning of the book are applicable to all horticulture crops in Ontario, with specific reference to ginseng where appropriate. General recommendations for ginseng will follow in separate chapters.

Ontario Ginseng Growers Association

The Ontario Ginseng Growers Association (OGGA) has been designated as the representative association for ginseng under the *Farm Products Marketing Act* and has the authority to collect a mandatory acreage fee to support research, education and promotion. All producers who grow $\frac{1}{4}$ ac or more of ginseng in Ontario are required to register with the OGGA.

The OGGA can be reached at:

1283 Blueline Rd.
Box 587
Simcoe, ON N3Y 4N5
Phone: 519-426-7046
Fax: 519-426-9087

Introduction

History

As early as 1643, the Portuguese explorer, Luthmin, described ginseng after his travels to China. The plant he found was *Panax ginseng* C.A. Meyer. It had been regarded for thousands of years as the most significant herb in Asia, where it was used as a wonder drug, cure-all and aphrodisiac. In fact, the root word for "panacea" (cure-all) and *Panax* are the same. Records from China dating back 5,000 years identify the plant and discuss its importance in traditional Chinese medicine. Jesuit Father Jartoux, who was stationed in China, wrote of Asian ginseng in 1702.

In 1716, the Jesuit priest Father Joseph François Lafitau in Quebec took diagrams from Father Jartoux to the Iroquois living near Montreal. They identified a similar plant, *Panax quinquefolius* L., growing in the hardwood forests near Montreal. Although a few

medicinal uses were identified by the First Nations, North American ginseng was not considered a significant medicinal plant prior to the start of the ginseng trade. Father Lafitau encouraged the Iroquois to find and dig the root for trade to the French fur traders. Over the next 30 years, ginseng harvest in Quebec reached over 9,000 kg per year. This nearly resulted in the complete disappearance of ginseng from Quebec, and ginseng collection slowed considerably for a few decades. However, by 1852, collection across eastern North America had increased to over 68,000 kg per year. By the late 19th century, destruction of forests and continued harvest of ginseng necessitated the first regulations by the Ontario government to limit the harvest of wild ginseng to protect wild populations.

In 1896, Mr. Clarence Hellyer established the first known ginseng garden under artificial shade in Canada near Waterford, Ontario. Over the next few decades, a few growers from Ontario and Wisconsin established the market for field-cultivated North American ginseng in Hong Kong. Eventually, North American ginseng became the preferred ginseng of the Chinese. The Ontario ginseng acreage expanded rapidly in the 1980s and 1990s to become one of the most important field-grown horticultural crops in the province. Acreage has remained fairly steady since the early 1990s.

The Ginseng Plant

American ginseng, *Panax quinquefolius* L., is a fleshy-rooted, perennial, herbaceous plant 45–60 cm in height (see Figure 3–1, *Diagram of a typical Panax quinquefolius plant*, next page). New plants arise each spring from buds on a rhizome at the "neck" of the root. The rhizome remains in place for the life of the plant, and root age can be estimated by the number of bud scars present.

Ginseng is a member of the Araliaceae family of plants. Members of the Araliaceae family that can be found in Ontario are *Panax trifolius*, dwarf ginseng, *Aralia nudicaulis*, wild sarsaparilla, *Aralia racemosa*, spikenard, and *Panax quinquefolius* (American ginseng). Ginseng is native to the mixed hardwood forests of northeastern North America from Quebec to Manitoba and south to northern Florida. Ginseng is hardy to zone 3. It is grown around the world in climatic zones between latitudes 34° and 45° N.

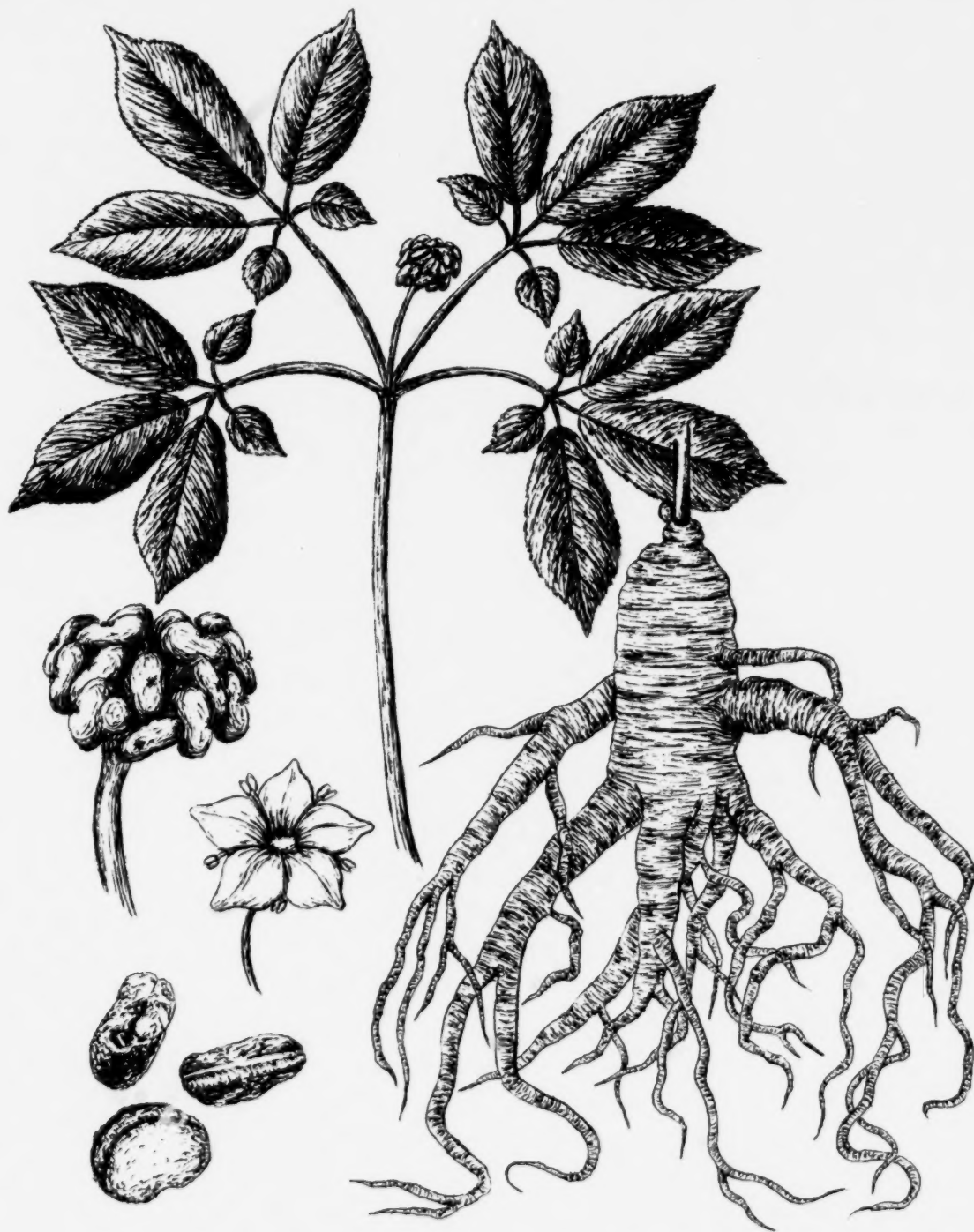


Figure 3-1. Diagram of a typical *Panax quinquefolius* plant

There are several features of ginseng that distinguish it from other horticultural crops.

- Ginseng seed requires 18–22 months of stratification (after-ripening) after the seed is harvested before it will germinate. This is discussed fully in *Seeds*, on page 28. This is problematic only when the stratification is interrupted, causing germination to be delayed.
- Ginseng must be grown in an environment that mimics its natural forest setting. This is discussed fully in *Ginseng Production Systems*, on page 30.
- Ginseng has no aerial growing point. Most plants develop progressively after emergence. As time passes, new leaves are formed, and flowers develop from growing points above ground. In ginseng, all plant parts are present at the time of emergence, including the flower head. The leaves unfold and expand as time passes, and the flower head elongates and enlarges during berry formation and seed set, but further development does not occur. Damaged plant parts are not replaced by new growth. Leaf damage has a direct effect on the photosynthetic capacity of the plant for the remainder of that season. The photosynthetic capacity — the ability of ginseng leaves to produce chemicals that increase root dry weight — is directly related to root yield. This feature of plant development emphasizes the importance of protecting the leaves from damage due to disease and mechanical injury. Early defoliation of the ginseng plant due to diseases may result in the loss of a year's growth of the root.
- Ginseng sometimes goes dormant for a year. In any garden, there will be some roots where there is no corresponding top growth. This is a natural feature of ginseng and is probably related to a survival mechanism in the deep forest. This occurs randomly, and once the canopy has developed, there is no indication of any missing tops. If plants are missing in clusters, check the roots for disease.

The Principle Growth Stages of Ginseng

The principle growth stages of ginseng have been described by Proctor et al in *The Annals Of Applied Biology*, 2003. (Proctor, J.T.A, Dorais, M., Bleiholder, H., Willis, A., Hack, H., and Meier, V. 2003. Phenological growth stages of North American ginseng (*Panax quinquefolius* L.). *Annals of Applied Biology* 143(3):311–317)

Germination and Bud Development

Ginseng is propagated by seed. After seed harvest, embryos mature in 18–22 months and require a

cool–warm–cool temperature stratification (maturation process). As the embryo matures, the seed coat splits. The new root emerges first, followed rapidly by the new shoot (Plate 1, page 89). Older stems arise each spring from a bud on an underground rhizome following a cold period that is necessary to satisfy dormancy (Plate 2, page 89). Buds swell and shoots begin to emerge once the soil temperature reaches 8°C. The hooked stem emerges through the soil in late April or early May (Plate 3, page 89). As the leaves unfold, an immature flower head is exposed. Two-year-old plants have an aerial shoot topped by a whorl of two 3–5-foliate leaves (a leaf with 3–5 leaflets) and a flower head. Three-year-old plants usually have 3 such leaves and a flower head. Occasionally plants will produce 2 shoots. This is a genetic trait, and selection and propagation of plants with 2 shoots can lead to increases in overall root yield in a garden. See Figure 3–2, *Germination of Ginseng Seed*, next page.

Leaf Development

In seedlings, food reserves for the developing leaf come from the seed. In older plants, this food supply comes from the root. During emergence, older roots can lose as much as 30%–50% dry matter content. This loss is recovered and surpassed through photosynthesis after the canopy is established. Development of the canopy in seedlings and mature plants takes about 4 weeks. The seedling shoot is a single trifoliate leaf (3 small leaflets atop a single stem) (Plate 4, page 89). Leaves begin to unfold when the seedling shoot reaches about 50% of its expected height, and development continues until the leaflets are horizontal. As shoots emerge from older roots, the leaves are folded. About 20%–50% of 2-year-old plants will have a flower head. Leaves on plants 2 years and older have 3–5 leaflets situated at the end of the petioles (prongs). It is common for 2-year-old plants to have 2 prongs, 3-year-old plants to have 3 prongs and 4-year-old plants to have 4 prongs. Plants rarely have more than 4 prongs, no matter what the age. Leaves begin to unfold at about half the plant's full height.

Root and Bud Formation

The transverse wrinkles on ginseng roots are due to expansion and contraction of the root in response to changes in temperature, which ensures that the root and rhizome remain below the soil surface. Ginseng seedlings have a dry-weight gain of about 0.2 g, 2-year-old roots about 2 g and 3-year-old roots about 3.5 g. The fresh weight of a 3-year-old harvestable root is about 20–30 g. Root weight gain starts in seedlings when the canopy has unfolded. In older plants, root weight begins to increase about mid-June, continuing until mid-September and is essentially linear. Bud length increases at the same time as root weight.



Figure 3-2. Germination of Ginseng Seed

Flower Head Development

Flower heads begin to develop on 3-year-old plants in June. Fifty per cent of growth is reached about mid-June, and the maximum elongation is reached by the end of June. (See *Ginseng Seeds and Flowers*, opposite page.)

Flowering and Fruit Set

The ginseng flower head is an umbel — all of the peduncles (small stems holding the flowers or berries) originate at the same point on the stem holding the flower head (also a peduncle). Ginseng flowers from the latter half of June until late July. Over the 6-week flowering period, about 35% of flowers are open at any given time. See Figure 3-3, *Ginseng Seed Head With Concurrent Flower Buds, Flowers and Berries*, opposite page.

Fruit Development

Once fertilized, ginseng seeds develop in the green berry (Plate 5, page 89). As the berries mature, they gradually change colour from green to dark red. The berries are ready to pick at the red stage and will fall off the umbel when they are dark red. Berry development usually lasts about 3–4 weeks, and during that period, the seed head will double in size. Berries are usually ready to harvest by mid-August. The berries on the seed head do not all ripen at the same time. There are roughly three ripening flushes during fruit development, beginning at the outer perimeter of the umbel. The developing embryo in the seed is not yet mature when the berries are harvested.

Senescence

Following berry harvest, the leaves will remain green for 3–4 weeks. Seedlings, which have no flower head, will start to show leaf yellowing during this period. The leaves of ginseng plants generally remain green for 100–120 days after emergence, but can stay green for

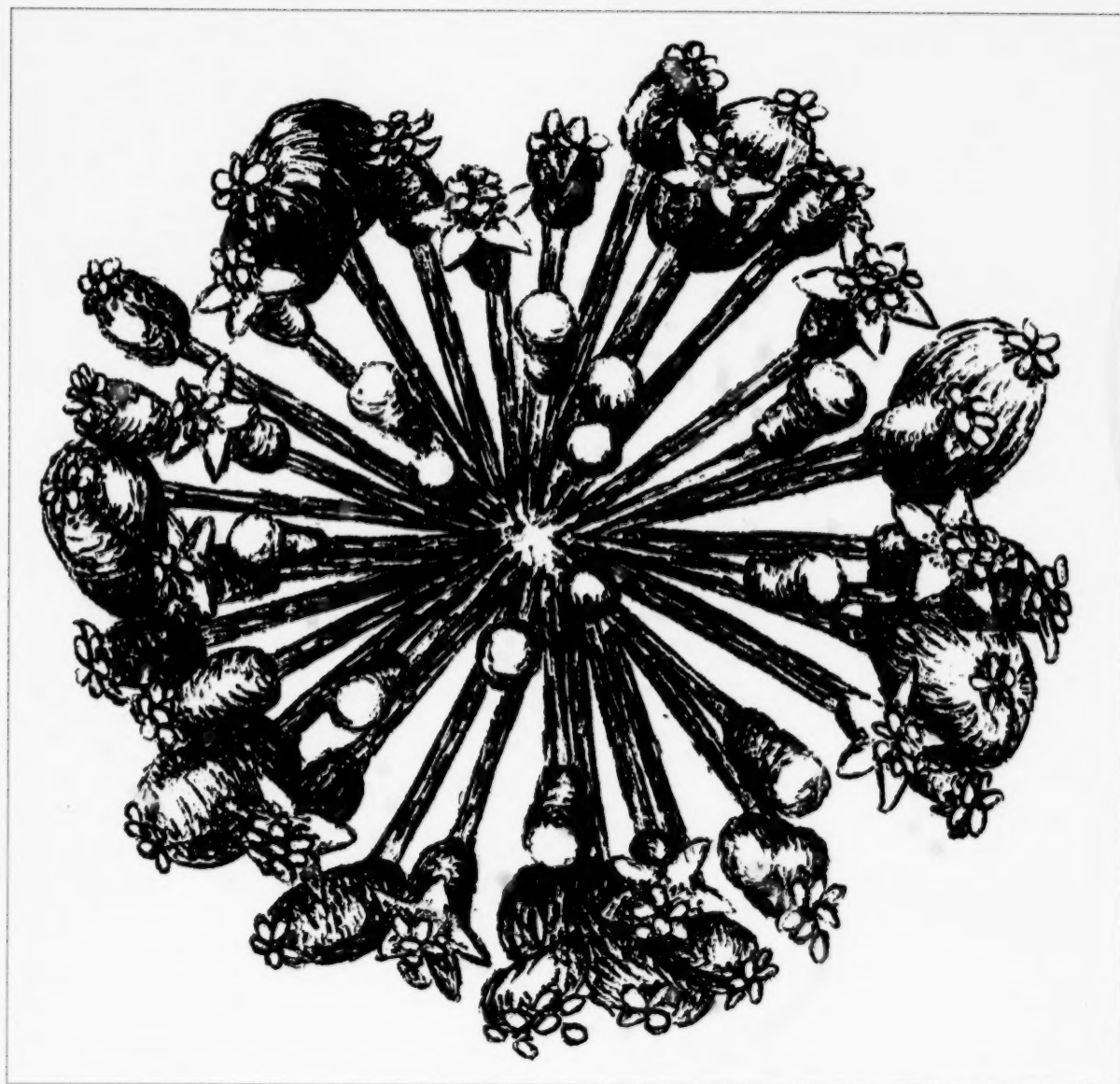


Figure 3-3. Ginseng Seed Head With Concurrent Flower Buds, Flowers and Berries

up to 200 days under perfect conditions. Once senescence is complete, the leaves turn yellow and drop, and the stems become yellow and dry. At this point, in a harvestable garden, the tops are necrotic (dead) and can be safely removed by scraping and the roots dug. The timing of senescence and eventual necrosis of the leaves can be manipulated somewhat by grower fertility practices. In gardens that are not harvested, the leaves drop onto the straw mulch, and the dry stems remain erect.

Ginseng Seeds and Flowers

Flowers

Ginseng Flower Development

Ginseng flowers are borne on an umbel — a flower cluster in which all the flower stalks radiate from the same point. The flower cluster of ginseng arises from the junction, or axil, of the leaves and stem of plants. While some flowering occurs on 2-year-old plants, the majority of flowers are found on plants 3 years and older. Flowering occurs in about three flushes and begins at the outside of the umbel and proceeds toward the centre. Ripening of the berries occurs in this same order.

Ginseng flowers over a 3–4-week period beginning in July. During this period, there will be seed heads that contain flower buds, flowers and berries at the same time. See Figure 3–3, *Ginseng Seed Head With Concurrent Flower Buds, Flowers and Berries*, previous page. Ginseng flowers are small and inconspicuous. The flowers have 5 greenish-white petals that are 2–3 mm across.

Pollination

Ginseng is self fertile. Pollination occurs between flowers within a single umbel or between flowers on different plants when pollinators are present. Insects that move from flower to flower appear to be natural pollinators, but bees are not necessary for fertilization.

Pollen tube formation can be interrupted in high temperatures, causing the seed to abort. Boron toxicity can also cause seed abortion.

Ginseng Seeds and Berries

Four-to-six weeks after flowering begins, ginseng berries are ripe enough to harvest (Plate 6, page 89). The berries are bright red when ripe (Plate 7, page 90). Each berry commonly contains 2 seeds (Plate 5, page 89), although 1 and 3 seeds can occasionally be found. Each umbel may contain 30–40 berries and subsequently 60–80 seeds. Newly harvested ginseng seeds are called “green seeds.” The pulp must be removed before stratification (Plate 8, page 90), (see Chapter 4, *Harvesting and Handling Ginseng Seeds and Roots*, on page 37).

Seeds usually set on 80%–90% of flowering plants in gardens 3 years and older. Under hot, dry conditions, seed set may drop to less than 50%. Weather conditions may cause abortion due to poor pollination or interference with seed development. Conditions causing seed abortion can occur under certain types of shade in hot weather. Low cloth shade can generate daytime highs that, if sustained, may cause the seeds to abort. Raising the shade cloth at intervals to form vents for the hot air to escape can mitigate this.

Embryo Development

The Ginseng Embryo

The ginseng embryo is immature at the time of seed harvest (Plate 9, page 90). An after-ripening period of 18–22 months is required for *Panax quinquefolius* seeds before germination. This process is referred to as “stratification.” A succession of cool, warm and cool temperatures is required for embryo growth.

The length of a normal embryo at harvest is about 0.5 mm. By the time the seed cracks and the young plant emerges, the embryo is 5.0 mm. Part of this growth (about 50%) occurs before seeding and part (the other 50%) after seeding.

One way to check if stratification is proceeding well is to check embryo size. If the embryo is too small just before seeding, it may not germinate the following spring. An embryo at the time of seeding should be 2–3 mm in length.

Seeds

Seed Size

A once-over harvest results in seed lots with great variability in size (Plate 10, page 90). Seed size affects germination and plant vigour. There is some evidence to suggest that seeds with a diameter of 4.8–5.6 mm (commercial seed grades 12–14) provide the best seeds for good ginseng production. Small seeds, under 4.8 mm in diameter, and extra large seeds, over 5.6 mm in diameter, may result in poor emergence and in smaller roots over the life of the garden.

Germination Testing of Ginseng Seed

Ginseng seed cannot be adequately tested for germination because of its need for stratification. However, it can be tested for viability. A viability test is a chemical test that indicates whether an embryo is breathing. This is often referred to as a “tetrazolium” test, because the tetrazolium dye that is used changes from clear to pink. Have the test done by an experienced individual who can correctly interpret the colour changes during the test. If the seed has dried out, frozen or appears in any way abnormal, it is advisable to get a tetrazolium test.

Planting Ginseng Seeds

Ginseng gardens are seeded mechanically. A variety of equipment is available to growers ranging from simple seeders with a seed-dropping mechanism to high-precision air seeders (Plate 11, page 90). In any ginseng-growing community, there are usually contract seeders who will do the job for the grower. Bed-forming is often done before seeding (Plate 12, page 90). Bed-forming and seeding equipment are sometimes combined. Apply straw as a mulch to the beds after seeding (Plate 13, page 91).

Ginseng Emergence

Ginseng seeds germinate in the spring following fall planting (see *Leaf Development*, on page 25, and Plate 4, page 89). Older gardens usually emerge in early to mid-May. Seed germination can be affected by storage temperatures of green seed and stratified seed. If stratification is interrupted during the warm period by cold temperatures or during the cold period by warm temperatures, germination may be delayed. There is evidence to suggest that germination can be delayed when seeds become too dry during stratification. There may be as many as 40% seedlings emerging in a 2-year-old garden when stratification has been interrupted.

Table 3–1. Seeding Rate and Equivalent 100% Plant Stand in the Seedling Year

Seeding rate (lb/acre)	Seeding rate (kg/ha)	Plant stand at 100% germination (no. plants/m ² of bed)
80	89	161
85	95	172
90	100	182
95	106	193
100	112	204
110	123	225
115	128	236
120	134	247

Seeding Rate

One kilogram of seed can contain anywhere from 11,000 to 19,000 seeds (5,000–8,500 seeds/lb). This will vary, depending on the seed size and moisture content. Ginseng is seeded at the rate of 89–112 kg/ha. See Table 3–1, *Seeding Rate and Equivalent 100% Plant Stand in the Seedling Year*, this page.

Plant Stand

Studies have shown that ginseng self-thins over 3 years to between 80 and 100 plants/m² and over 4 years to between 35 and 70 plants/m², regardless of the initial seeding rate or plant stand in year one.

Research has shown that the more crowded the roots are in the first year of development, the smaller the individual roots will be. High seeding rates may lead to more “pencilly” roots but pencil roots may also be a factor of soil texture — the less compact the soil, the longer and thinner the roots.

Flower Bud Development

When ginseng emerges through the soil in the spring, the flower bud is already present. The flower bud is attached at the junction of the stems. As soon as the leaves have unfolded, the flower bud begins to elongate. Eventually it can stand several centimetres above the leaf canopy. Because of the natural genetic diversity of ginseng, there will be flower heads that are above the leaf canopy and flower heads that are within it, making it difficult to harvest berries mechanically. A typical flower head will produce about 40 berries. Berries usually contain 2 seeds.

Deflowering (Debudding) Ginseng

Once the leaves have unfolded, the plant's energies are concentrated on the reproductive cycle. Root growth is minimal during seed development. Root growth

Table 3–2. Deflowering Decision Matrix

Seed/Root Values	Roots @ \$10/lb	Roots @ \$20/lb	Roots @ \$30/lb	Roots @ \$40/lb
Seed @ \$10/lb	(\$2,000)	(\$7,000)	(\$12,000)	(\$17,000)
Seed @ \$20/lb	\$1,000	(\$4,000)	(\$9,000)	(\$14,000)
Seed @ \$30/lb	\$4,000	(\$1,000)	(\$6,000)	(\$11,000)
Seed @ \$40/lb	\$7,000	\$2,000	(\$3,000)	(\$8,000)
Seed @ \$50/lb	\$10,000	\$5,000	\$0	(\$5,000)
Seed @ \$60/lb	\$13,000	\$8,000	\$3,000	(\$2,000)
Seed @ \$70/lb	\$16,000	\$11,000	\$6,000	\$1,000
Seed @ \$80/lb	\$19,000	\$14,000	\$9,000	\$4,000
Seed @ \$90/lb	\$22,000	\$17,000	\$12,000	\$7,000

resumes about mid-July when the berries begin to turn red. Deflowering the plant just as the flower bud begins to elongate will redirect the plant's energies to the developing root. Research has shown that deflowering can result in a 25%–30% increase in root weight. Growers must choose between the development of seed and an increase in root weight.

Some 2-year-old plants will have flower buds, but a ginseng garden is usually 3 years old before it has the potential for a seed crop. Most gardens will yield an average seed crop of 336 kg/ha (300 lb/acre) but some can yield as much as 560 kg/ha (500 lb/acre). The decision to deflower is made early in the season, and there is a certain risk associated with it. Some growers choose to deflower and leave only a portion of their garden for seed development. In a hot, dry year, especially under low cloth shade, high temperatures may cause abortion of the seeds shortly after fertilization. The practice of deflowering is one of the factors affecting the availability and cost of seed.

Deciding to Deflower

Table 3–2, *Deflowering Decision Matrix*, this page, compares economic returns with and without deflowering. The starting point is an average-yielding 3-year-old garden — 2,800 kg/ha (2,500 lb/acre) — where both seeds and roots will be harvested. What is the economic benefit of deflowering?

Using the Matrix

A few assumptions need to be made:

- that the cost of deflowering is the same as the cost of picking seed
- that the average seed yield is 336 kg/ha (300 lb/acre)
- that the average increase in root weight is 560 kg/ha (500 lb/acre)

Interpreting the Deflowering Matrix

Using the matrix in Table 3–2, determine the economic impact on 0.4 ha (1 acre) of ginseng with and without deflowering. Numbers in brackets represent the increase in returns due to increased root weight after deflowering. Numbers without brackets represent the increase in returns if seed is picked and sold as well as roots. It is not always more profitable to deflower. The sale of both root and seed are events that will take place in the future. There is no guarantee that markets for the sale of either will be strong.

For example, if root prices are \$20/lb, and seed prices are \$20/lb:

- With deflowering, gross sales of roots amount to $3,000 \times \$20 = \$60,000$.
- Without deflowering, gross sales of roots and seeds are $2,500 \times \$20 + 300 \times \$20 = \$56,000$.
- The difference is \$4,000.
- Because the \$4,000 is in brackets in the matrix, it means that deflowering will bring \$4,000 more in gross returns than letting seeds develop and selling both seeds and roots.

In other words, the grower can make \$4,000 more by deflowering and getting a higher root yield than by selling an average root yield plus seeds.

However, when root prices are \$20/lb and seed prices are \$40/lb, there is \$2,000 more to be made if the flowers are left on, and both seeds and roots are sold, even though root yields will be lower.

Diseases of Seed Heads and Flower Heads

The flower and seed heads of ginseng are susceptible to three fungal diseases that can cause economic loss.

Alternaria Diseases of Seed and Flower Heads

Alternaria panax can invade the stalk supporting the seed head or the small stalks supporting the individual seeds. Infected stalks shrivel and become tan coloured. Once these stalks shrivel, the seed aborts (Plate 14, page 91). For a complete discussion of alternaria diseases of ginseng, see Chapter 5, *Diseases, Pests and Disorders of Ginseng*, on page 47.

Botrytis Diseases of Seed and Flower Heads

Botrytis cinerea can infect developing berries. In most crops, *Botrytis* enters the flower around the time of petal drop. The exact timing of entry into ginseng berries is not known. Infected berries take on a purple colour and begin to dry out (Plate 15, page 91). Eventually, these berries abort. Berries affected later will develop many conidia and take on a grey, fuzzy appearance (Plate 16, page 91). For a

complete discussion of *Botrytis* diseases of ginseng, see Chapter 5, *Diseases, Pests and Disorders of Ginseng*, on page 47.

Powdery Mildew

Powdery mildew can also affect ginseng berries. The powdery mildew fungus causes a late-season disease and may be more severe in some years than others. Developing seed heads become covered with a white, “powdery” mass of fungal spores. The disease appears superficial but can cause berries to shrivel and may interfere with seed development.

Ginseng Production Systems

There are several production systems for growing ginseng:

- **field-cultivated**, under artificial shade. Throughout this book, “field-cultivated” will be referred to as “commercial” ginseng.
- **woods-grown**, using the forest as a natural canopy but using soil preparation, fertility and pest control measures
- **wild-simulated**, where seeds are planted in a natural setting. Wild-simulated is sometimes called “wild-cultivated.”

The most common production system used in Ontario is field-cultivated. Field cultivated ginseng is grown under artificial shade (see *Planting a Commercial Ginseng Garden*, opposite page). In Ontario, all ginseng production is subject to the *Endangered Species Act*, 2007. A specific exemption regulation is in place for field-cultivated ginseng. Woods-grown and wild-simulated ginseng production is only allowed if authorized through a permit or agreement under the Act. See *American Ginseng in Ontario and the Endangered Species Act*, 2007, this page.

American Ginseng in Ontario and the Endangered Species Act, 2007

There are very few stands of wild American ginseng remaining in Ontario forests (Plate 17, page 91) (Plate 18, page 91). Surveys conducted between 1985 and 1997 indicated a drop in the number of identified wild sites during that time span. This drop in population has been attributed to harvest of wild populations and loss of habitat to logging activities.

In June, 2008, the *Endangered Species Act*, 2007 came into effect in Ontario. American ginseng is listed as an endangered species under the Act. Members of the Ontario Ginseng Growers Association are exempt

by regulation from the Act as long as they meet the following requirements:

- roots are produced under artificial shade on lands licenced under Ontario Regulation 340/01 (Designation – Ontario Ginseng Grower's Association), and
- growers do not use seeds or other plant material collected from the wild in Ontario after June 30, 2008

At the time of printing of these recommendations, it is illegal to plant, harvest, possess, buy, sell, lease or trade ginseng collected from the wild in Ontario without authorization through a permit or agreement under the Act. This includes both wild-simulated and woods-grown ginseng. Contact the Ontario Ministry of Natural Resources for the current status of the *Endangered Species Act*, 2007, as it pertains to ginseng production outside of a commercial field environment:

Ontario Ministry of Natural Resources
Phone: 1-800-667-1940
Website: www.mnr.gov.on.ca

Export of ginseng from Canada is governed under the Convention on International Trade of Endangered Species of Flora and Fauna (CITES). Ginseng is listed under Appendix II of this Convention. It is illegal to export wild ginseng from Canada. See *CITES Requirements for Exporting Ginseng*, on page 44.

Commercialization of Ginseng

In the 1700s, ginseng roots were collected from the forest, dried and exported to China. Ginseng exports from North America rivalled the fur trade.

By the mid-1800s, attempts were made to cultivate ginseng. Because the plant is a native of the forest floor, it is important that cultivation techniques mimic the forest environment. The first attempts at cultivation outside the forest were done under producing apple trees.

As the industry progressed, artificial shade material was used. Ginseng was grown in raised beds and the beds were covered with mulch.

As of July 2009, there are approximately 2,500 ha of cultivated ginseng in Ontario. The age of these gardens varies from 1–5 years. The majority of ginseng gardens in Ontario are harvested at the end of the third or fourth year of growth. The limiting factor in determining when to harvest ginseng is garden health.

Planting a Commercial Ginseng Garden

The objective of commercial production is to reproduce the environmental conditions of the forest in a field setting. This is usually accomplished through construction of artificial shade and mulching.

Aside from shade material, the primary difference between field cultivation and forest cultivation is one of fertility and plant protection. Through careful soil preparation and protection from pests, cultivated ginseng plants will produce a marketable root in 3 years.

Site Selection

Selecting an appropriate site for commercial ginseng production is the single most important choice a grower makes. Successful field cultivation of ginseng depends on mimicking the environmental conditions of the plant's natural home on the forest floor. The basic requirements of site selection are:

- good drainage
- moderate organic matter
- soil textures ranging from silt loam to sandy loam
- the availability of sufficient calcium

Soil Type

Several types of soil are suitable for ginseng production if the basic requirements of site selection are met. Soil type may also affect root shape. Very sandy soils with low organic matter tend to produce long, pencilly roots. Some markets value this type of root. Other markets require a stubbier, chunky root.

Soils with gravel or stones will allow water to percolate too quickly and may be prone to temperature fluctuations. Such objects in the soil may also affect root shape.

Any soil where ginseng is grown must have good drainage. Do not plant poorly drained areas of a field to ginseng. Subsoil drainage is important. If the soil becomes saturated, root disease may develop. It is a good practice to do a soil profile in the prospective field. This will help identify subsurface layers that will have an impact on drainage. A layer of mulch on top of the beds slows the loss of soil moisture. If subsoil drainage is not sufficient, soil in the beds will remain near capacity and encourage the development of *Phytophthora*.

Water Management

Ginseng does not thrive in wet areas. Avoid low spots in fields and avoid areas of surface water runoff. Grade gardens to facilitate the removal of surface water.

Grading the Garden

Grading a garden before planting is always the best option. When laying out a garden, design beds so that water flows freely from them and out of the garden. In areas where water tends to flow during the early spring and after periods of rainfall, a grassed waterway can be maintained to assist water movement.

There are several design factors that assist in water management.

- Dig a perimeter trench that is slightly lower than the ends of the garden trenches (Plate 19, page 92).
- Drain the perimeter trench into a collection pool.
- Extend trenches at the end of a downward slope to keep water moving during periods of heavy rain.
- Dig a trench that follows the natural water flow. This trench may cut through beds in low areas.
- Insert Hickenbottom drains.

Gardens that are planted over an entire field without regard for waterways invariably have areas of *Phytophthora* infections where the water flows regularly (Plate 20, page 92). Movement of machinery through these areas will spread disease throughout the entire garden.

Dealing With Excess Water

Wet areas in a garden can be hot spots of phytophthora root rot.

Collection pools can be dug to contain water runoff from ginseng gardens. Such a pool should be in a low area and be deep enough to hold water from runoff after heavy rains.

When water stands in a trench, it also saturates the adjacent bed. Ginseng roots can reach well down into the soil in the beds, and root tips adjacent to a flooded trench will be in danger of infection by *Phytophthora*. When the water subsides, the trench will be "greasy," and soil-borne pathogens can be spread throughout the garden on machinery and boots.

If there are areas of a garden where water tends to pool in the trenches (Plate 21, page 92) and stand for periods of time, add wood chips or other absorbent material (such as a layer of thick straw) to the trenches to prevent splashing. Splashing from wet trenches in diseased areas is a leading cause of foliar phytophthora blight.

Water management cannot be stressed enough. If there are low, wet areas in a new garden, do not plant seed in them. Empty spaces do not spread — disease does.

Dealing With Soil Compaction

Beds in a ginseng garden are formed along and between rows of posts that support the shade material.

Application of fertilizer and pest control products requires repeated driving on the same trenches because this equipment must fit between the post rows. The extensive maintenance required in ginseng gardens often leads to compaction in these trenches. Compaction in the trenches can be alleviated to some extent by subsoiling the trench. This is better done before heavy rains.

Site Preparation

Make initial adjustments in soil nutrition in the preplant year. Nutrient levels in the soil will vary throughout any given field. Ideally, the soil in a field should be sampled on a grid with the exact location of each sample determined with GPS. This will allow the field to be mapped indicating where nutrients need to be added.

Nutritional Requirements

There is little information to suggest a nutrient regime for ginseng production in Ontario.

Nitrogen (N)

The recommended nitrogen application rate for ginseng is 40 kg N/ha applied every year of production as a broadcast application in the spring prior to emergence. Nitrogen rates exceeding 50 kg N/ha do not increase root yield and may reduce yield. The rate of nitrogen applied has little effect on the root ginsenoside concentration. Research has shown that nitrogen application requirements for ginseng using fertigation should be similar to broadcast application.

Calcium (Ca)

Research has shown that calcium is essential, both for the growth of the ginseng plant and the health of the root. Most soils in the ginseng-growing areas of Ontario have moderate levels of calcium. Soil calcium can be made more available to plants by adjusting the soil pH. When pH is adjusted with the addition of lime (see Table 2–3, *Lime Requirements to Correct Soil Acidity Based on Soil pH and Soil Buffer pH*, on page 11), calcium may also be added. Calcium availability decreases as the pH drops below 6.5.

Calcium deficiency symptoms have been noted in ginseng. Once the canopy is established, calcium is not redistributed in the leaves. Leaves deficient in calcium will develop necrotic edges, and the leaf tissue dries progressively toward the centre.

The availability of calcium is a function of the total calcium supply, soil pH, the exchange capacity of the soil and the soil type. Calcium uptake in plants is depressed by ammonium-based nitrogen, and high levels of potassium, magnesium, manganese and aluminum.

Boron (B)

Research at the University of Guelph has shown that ginseng requires very little boron. Growers are not advised to add boron to soils that test above 0.5 micrograms of boron per millilitre (0.5 ppm). Boron toxicity in ginseng is expressed as reduced emergence, necrosis, chlorosis, premature seed drop and reduced root yield (Plate 22, page 92).

Phosphorus (P)

Past research has shown that ginseng responds positively to phosphorus. Insufficient phosphorus will result in smaller roots. It has also been shown that low phosphorus levels contribute to "pencil root" in seedlings. Weather-induced phosphorous deficiency may be apparent in cool, dry or saturated soils. Cool, wet conditions sometimes occur in the spring in ginseng gardens. This problem usually diminishes when the soil warms up. Phosphorous availability is highest at pH 6.5. See Table 2-5, *Phosphorus Requirements for Ginseng on Mineral Soils*, on page 12.

Potassium (K)

Plants need potassium as much as they need nitrogen. Potassium is involved in the production of the plant's structural components. It influences the process of photosynthesis and water uptake by roots. It also plays a role in starch and sugar content and overall quality. Potassium also aids in disease and insect resistance. See potassium recommendations for ginseng gardens in Table 2-6, *Potassium Requirements for Ginseng on Mineral Soils*, on page 13.

Soil pH

Ginseng is found in the wild in Ontario in soils ranging from pH 4.5–pH 7.1. The nutrition and soil pH conditions in the natural forest setting for ginseng can give a good indication of the requirements in the field. See Table 3-3, *The Range of Nutrient Conditions at Wild Ginseng Sites in Ontario*, this page. Adjustment of pH is sometimes necessary for field cultivation. pH is commonly adjusted to between 6.0 and 6.5 for new gardens. This pH range allows the best uptake of soil nutrients. If the pH is too low, the plants will be stressed and will be more susceptible to root disease and sometimes foliar disease.

Weed Management

Any field considered for the future planting of ginseng should have 1–3 years of preparation before seeding. This allows time to reduce the number of weeds in the area before the ginseng crop is planted. The most effective means of controlling weeds in ginseng is the management of that field before seeding. See *Weeds*, on page 72, for methods of dealing with weeds in ginseng and Table 6-4, *Weed Control Recommendations for Ginseng in Ontario*, on page 76.

Table 3-3. The Range of Nutrient Conditions at Wild Ginseng Sites in Ontario¹

pH		% organic matter	Soil concentration in ppm								
			P	K	Mg	Ca	Zn	Mn	Cu	Fe	B
L	4.5	2.9	11	45	51	269	1.9	26.6	0.1	21	0.43
H	7.1	5.8	49	99	498	2,283	4.1	40	1.0	207	0.9

L = low, H = high

¹ The range of values in this chart does not represent all the wild sites in the province.

Cultural practices in the preplant year can result in reduction of weed populations. Early in the season, perennial weeds that have grown to a height where they are most vulnerable (15 cm) can be treated with a non-selective, non-residual herbicide. Populations of annual broadleaf weeds and grasses can be partially controlled by a series of shallow cultivations. Preferred practices in the preplant year include application of manure followed by a plowdown cover crop followed by fumigation. Fumigation will control resident weeds. Most weeds in ginseng, however, are introduced either on the mulch applied to the beds at seeding or on the wind from neighbouring fields.

Organic Matter

The organic matter content of hardwood forest soils where ginseng is found ranges from 2%–7%. Soil organic matter content cannot easily be adjusted. Additions to the soil are generally in the form of plant residues, manures and other organic materials. Organic matter is lost through soil erosion and oxidized (burned-off) as a result of tillage.

Building Organic Matter With Manure and Compost

Well-composted manure can be added in the preplant year to improve soil tilth. Add manure at least 4–6 weeks prior to fumigation and work it in sufficiently to break apart any clumps. Growers traditionally add 20–80 tonnes of manure/ha (10–40 tons/acre). Manure has significant fertilizer value but can also supply vital organic matter to the soil. Manure is one of the few ways to bring in an "outside source" of organic matter.

If using manure to build soil organic matter, it is important to know the characteristics of the manure. There are several types of manure and many different feeding and bedding systems that impact its composition. See Table 2-10, *Available Nutrients and Value for Manure From Various Livestock Types – Solid Manure*, on page 15.

Building Organic Matter With Cover Crops

Cover crops add organic matter, but the amount varies depending upon the cover crop species and the conditions under which it is grown.

Cover crops that take up nitrogen can help reduce nitrogen losses due to leaching.

Cover crops can help reduce compaction and improve soil structure. The addition of the plant top and especially root matter helps improve water infiltration and holding ability. It can also decrease soil bulk density. Deep-rooted cover crops can help decrease the impact of soil compaction. Of the cover crops available, ginseng growers in Ontario most commonly use rye.

For more information on cover crops, planting and management prior to ginseng establishment, see Chapter 2, *Soil Management and Fertilizer Use*, on page 7.

Fumigation

Preplant fumigation is recommended for most ginseng soils. In addition to nematodes, fumigation may also help to partially control certain soil-borne diseases, such as *pythium* and *rhizoctonia*, that affect ginseng quality and yield. See Chapter 5, *Diseases, Pests and Disorders of Ginseng*, on page 47, for more information on soil-borne pests.

In Ontario, most soil fumigation is performed by custom applicators. Recommended rates are usually shown as a range (e.g., 225–450 L/ha). Fumigants may be broadcast or banded. For disease control, use concentrations near the upper limit. Always follow the manufacturer's directions about rate and methods of use carefully.

Fumigate in summer, ideally 4–6 weeks prior to seeding. If undecomposed organic matter is present in the soil, it may interfere with the fumigation process. Allow sufficient time for cover crops or manure to break down prior to fumigation.

The effectiveness of fumigation depends on soil temperature and moisture and on how well the land has been prepared before fumigation. Clods of soil and undecomposed organic matter will interfere with the distribution and dissipation of fumigants. Ensure that clods are adequately broken down prior to fumigating. Most fumigants work best at soil temperatures between 10°C and 24°C at 15 cm deep. However, the optimal temperature range varies from product to product. Consult the label for optimal temperature ranges. If the soil is too dry, fumigants will dissipate too rapidly. In wet soil, fumigants will not be able to dissipate properly

and may cause plant damage. Follow the manufacturer's instructions about appropriate soil moisture levels and the length of time the soil is to be "sealed."

See Table 6–2, *Preplant Fumigation of Ginseng in Ontario*, on page 75, for fumigation recommendations. Higher rates are applied to ensure control of root pathogens. *Pythium* is present in most soils in Ontario, and fumigation is usually effective in reducing the population of this fungus. *Rhizoctonia* can be controlled to some extent by fumigation. Fumigation does not completely control all pathogens.

Prior to seedbed formation, till the soil thoroughly to aerate it and ensure that all fumigant odour has dissipated. Two weeks of aeration with periodic shallow disking should allow trapped vapours to escape.

It is very important when preparing seedbeds for ginseng to make sure no unfumigated soil is brought up onto the beds. Unfumigated soil will introduce nematodes and soil-borne disease organisms into the seedbed and could increase the incidence of damping-off and diseases associated with the presence of *Rhizoctonia* and *Pythium*.

Populations of soil microorganisms remain low for several months after fumigation. After that time, recolonization occurs. In a ginseng garden, recolonization by pathogens depends on sanitation and the protection of the garden against blowing sand and soil and the movement of surface water. Pathogens can enter a new garden on machinery, animals, people working in the garden, in unfumigated soil and in surface water runoff. Straw is not usually a source of ginseng pathogens.

Bed Formation and Seeding

Once the field has been adequately prepared, determine the direction of the beds. Form beds so that air movement through the garden is facilitated. This will be determined by the direction of the prevailing winds. Air should move along the length of the garden. Lay out beds so that surface water drains out of the garden. Before ginseng is seeded, place posts to allow for the erection of a shade structure (see *Managing Shade Requirements*, opposite page). After the posts are set, form the beds (Plate 12, page 90). Occasionally, growers prefer to form the beds before installing posts.

Ginseng can be seeded with a range of seeding equipment (Plate 11, page 90). See Table 3–1, *Seeding Rate and Equivalent 100% Plant Stand in the Seedling Year*, on page 29, for common seeding rates and corresponding 100% plant stand. Seeding rates commonly vary between 89 and 112 kg/ha. Ginseng can be seeded any time after mid-summer.

Table 3-4. Critical Soil Temperatures in Ginseng Gardens

Temp.	Effect
-4°C	Crown rust may occur on all ages of roots.
-8°C	Seed viability may be affected below this temperature.
-11°C	Viability of seedling roots is affected.
-16°C	Viability of 3-yr-old roots is affected.

Take care not to store stratified seed below 8°C. If stratified seed is chilled before seeding, dormancy may be affected, and the seed may germinate in the second year after planting rather than the first.

Management of the New Garden

Managing Soil Temperature and Moisture

A deliberate effort is made in gardens to mimic the forest floor. This is done by applying 5–10 cm of mulch to the surface of raised beds. The most common mulch is straw (Plate 13, page 91). Growers generally use wheat, oat or rye straw. The choice of mulch depends on availability and price.

Application of mulch preserves soil moisture and moderates soil temperature. The soil temperature below straw mulch usually remains above -5°C, even in a very cold winter. This is a critical temperature in the development of rusty root (see Table 3-4, *Critical Soil Temperatures in Ginseng Gardens*, this page).

The mulch also helps to prevent “heaving” of the roots in the spring. Soil temperatures warm more steadily in the spring without extreme fluctuations under the mulch. Roots that heave out of the soil are usually found on the sides of the beds where the mulch is thinnest. These roots often freeze and thaw and are attacked by weak pathogens such as *Pythium*. Fluctuating temperatures can be more damaging to both roots and seeds than prolonged low temperatures.

Both soil temperature and moisture are managed through the application of mulch to the surface of the beds. Once the beds are seeded, it is important to follow with a mulch immediately. If the application of mulch is delayed, the newly planted seeds may dry out. While drying itself may not seriously harm the seed, it may make it more susceptible to chilling injury during the winter months, thus contributing to poor emergence. Seed that has become too dry may be delayed in germinating.

There is some evidence to suggest that, under certain environmental conditions, rye straw as a mulch has allelopathic properties. Allelopathy in this case refers to the ability of the rye straw to inhibit the

germination of ginseng seeds and reduce plant vigour (Plate 23, page 92). This will only occur under certain environmental conditions that have not been characterized.

Some growers seed oat or rye as a nurse crop at 180–273 L/ha when seeding the ginseng (Plate 24, page 92). The oats will germinate in the fall, act as an anchor for the straw mulch and die off through the winter. Research has shown that this has no negative effect on the ginseng. It has not been shown to enhance plant stand. If rye is used as a nurse crop, the rye that germinates in the fall will survive through the winter and can become a weed problem in the spring.

Agriculture and Agri-Food Canada has assessed the effect of bark mulches in suppressing weeds and fungal diseases. Research has indicated that bark mulch improves weed suppression in young gardens. In a comparison trial with oat straw, white pine (*Pinus strobus*) bark mulch consistently improved root shape and resulted in higher plant populations. In these trials, yields at harvest were higher with pine bark mulch. A mixture of white and red pine (*Pinus resinosa*) bark mulch reduced the incidence of damping-off by *Rhizoctonia solani*. Pine bark did not reduce the pH of the soil beneath the mulch.

Managing Shade Requirements

In commercial ginseng production, the erection of a shade structure affects both the garden temperature and the light intensity. In a new garden, the posts are usually set before seeding, but the shade material is not “pulled” until the following spring when the new plants emerge.

Commercial ginseng growers use three types of artificial shade: wooden lath, low polypropylene cloth and high polypropylene cloth.

Wooden Lath Shade

(Plate 25, page 93) These wooden screens are constructed by growers. Wood lath 0.8 cm x 3.0 cm x 1.22 m is stapled to supporting boards 1.25–2 cm apart to form a screen. A standard wooden screen is 3.8 m x 3.4 m. These wooden screens are wired to galvanized metal or wood rails. The rails are supported by wooden posts, 2.4–2.7 m in length. It takes approximately 875 wood posts to erect shade for 1 ha of ginseng. Posts are placed 3.8 m apart between rows and 3.6 m apart within rows. There are 2 half beds and 1 full bed between post rows in gardens shaded with wooden lath.

The standard wooden shade screen has a light penetration of 17.8%. Various materials can be used as lath. Light penetration can change as the screen

ages, depending on the source of wood. Balsam fir shrinks 1.6 mm in the first month and an additional 3.2 mm in the first year. This shrinkage can increase light penetration by 4%. White pine, black pine and black spruce have less shrinkage. Wood lath shade can last 8–12 years and can be reused one or two times depending on its condition.

Low Cloth Shade

(Plate 26, page 93) Low cloth shade is about 1.8–2.5 m in height. Woven polypropylene strips 7.3 m wide are strung, with the use of grommets and S-hooks, along tensile wires the length of the garden. Shade cloth may vary in the amount of light penetration. Weave patterns can be obtained that block 74%–82% of the light. The cloth strips are wider than wooden lath screens, and gardens are set up accordingly. There are 2 half beds and 3 full beds between post rows in low cloth gardens.

High Cloth Shade

(Plate 27, page 93) High cloth shade is about 3–3.7 m in height. The polypropylene cloth that is used for high cloth shade is 10.9 m wide. The difference between the high cloth and low cloth systems is the height and spacing of the posts and the fact that metal posts are more often used in high cloth shade. There are two half beds and five full beds between post rows in high cloth shade gardens.

Managing Canopy Temperature

Temperature between the plant canopy and the shade material in a ginseng garden depends on the type of shade erected.

Low wood shade and high cloth shade are cooler in summer than low cloth shade.

Temperature and humidity under low cloth shade can remain high both day and night unless vents are provided for hot air to rise out of the garden. Research has shown that air temperatures in the ginseng canopy are up to 6°C higher on a sunny day than the air above the shade structure. On hot days, the additional heat in the plant canopy can restrict growth of the plant. The use of low cloth shade may result in slightly larger roots. This may be because high-temperature conditions are conducive to poor seed set. See *Ginseng Seeds and Flowers*, on page 27, for a discussion of flower development and seed set in ginseng.

Avoid situating gardens in locations that may have restricted air flow. Gardens situated in protected corners of fields surrounded by woods usually have a higher incidence of both foliar and root disease. In addition, low cloth shade can restrict air flow. Research has shown that wind speeds under the shade can be up to one-sixth of the wind speed above the shade structure. Low wind speed can reduce drying of the canopy and provide favourable conditions for foliar disease. These conditions can be improved by providing vents for hot and humid air to escape the shade structure and by establishing gardens in open sites to facilitate air movement.

4. Harvesting and Handling Ginseng Seeds and Roots

Seeds

Harvesting Ginseng Berries

Berries are harvested, by hand, when they are red. When the berry is red, the embryo is ready to undergo temperature stratification. Seeds from fully ripe, red berries give higher emergence rates than seeds from green berries.

Depulping Ginseng Berries

Berries are usually collected into baskets (Plate 6, page 89). Before beginning the stratification process, they must be depulped. One method is to leave the berries in burlap bags for several weeks in a cool shed to rot the outer pulp. Some growers also trample the berries to facilitate degradation of the pulp, although this increases the chance of seed infection by *Botrytis* and *Alternaria*, which are common moulds that grow on rotting berries.

It is preferable to depulp berries using a mechanical depulper (Plate 28, page 93) within 2 days of picking. Seeds are processed in a machine (a modified grater) that uses water to rinse the pulp away. The pulp-filled water from the depulper can be spread back on the field and incorporated. Do not add it to streams or ponds as it will create a biological oxygen deficit.

It takes approximately 2 kg of berries to produce 0.45 kg of seeds.

Handling Green Seed

Newly harvested, depulped seed is called "green seed" (Plate 8, page 90). Keep green seed moist and stored between 8°C–10°C. It can be successfully stored as low as 5°C, but if the temperature is lower than this, there is a risk of delayed germination. When germination is delayed, the ginseng seeds emerge in the second year after seeding. There is often a small percentage of seeds that do not emerge until the second year, even when temperature guidelines have been followed.

Green seed can also be buried for stratification. The soil temperature should be below 15°C. If the soil is too warm when seed is buried, early growth may occur. Soil temperatures in a buried seedbox rarely fall below the freezing point and rarely rise above 20°C.

Stratifying Ginseng Seeds

Depulped seeds are placed in a seedbox for stratification. The seed is mixed with 2 or 3 parts sand by volume.

Ginseng seed is traditionally stratified by burial below ground (Plate 29, page 93). In recent years, more growers are stratifying seeds by storing them above ground in temperature-controlled chambers. Spring germination in 8 months has been achieved in research trials using gibberellic acid at the University of Guelph. This procedure may hold some promise for the future. Gibberellic acid is currently not registered for use on ginseng.

Below-Ground Stratification (Traditional)

To stratify seed below ground, mix the seed with clean sand in a ratio of 1 part seeds by volume to 2 or 3 parts sand.

Place the seed-sand mixture into the seedboxes. Plastic seedboxes with enough holes to allow good drainage are ideal. Wooden seedboxes carry the risk of transferring disease from year to year. A top layer of about 15–20 cm of sand or straw is recommended to prevent the drying of seeds near the surface of the box.

Bury seedboxes in the ground so the top layer of seeds is at least 20 cm below the soil surface. Temperature variations below this level are minimal. Ginseng seed is sensitive to temperature variations during stratification. Excessive cold or heat can delay or induce germination. Do not bury seedboxes in forest soil or in fencerows where there are trees or in areas where forests were recently cleared. Certain crops, such as clover, can harbour *Cylindrocarpum* without becoming infected themselves. Burial in such an area would carry a higher risk of infection for ginseng seed.

A number of problems can arise during traditional stratification. If temperatures fluctuate, up to 10% premature germination can occur in the first 8 months of stratification. Seed that germinates prematurely will die and become infested with fungi that may pose a threat to other, healthy seeds. Buried seed can become infected by soil pathogens such as *Fusarium*, *Cylindrocarpum*, *Pythium* and *Rhizoctonia*. These fungi can move through the soil or be carried by soil, insects or water and can enter a buried seedbox wherever it is exposed to the soil.

Above-Ground Stratification

Research has shown that ginseng seed can be stratified above ground in a temperature-controlled environment. Above-ground stratification can result in low germination rates if the warm period is too warm or too long. The best germination rate that can be expected using above-ground stratification is 80%. Germination rates can be as low as 20% if temperature or moisture control is erratic.

To begin above-ground stratification of ginseng seed, mix green seed with sand as for below-ground stratification (1 part seeds by volume to 2 or 3 parts sand). Place seed-sand mixture in plastic boxes. Take care that the boxes do not dry out. Research has shown that maintaining about 10% moisture is adequate. Hold the seeds at 3°C for 9 months (mid-August or early September to mid-May) and then for 3 months at 21°C (June through August). During this time, the embryo will grow from 0.5 mm to approximately 3 mm. Remember that ginseng needs cool-warm-cool stratification. The second cool period comes after the seed is placed in the garden beds.

Diseases of Ginseng Seeds

Garden health begins with the planting of healthy seed. The first evidence of potential seed problems can often be found after stratification and before seeding.

Before or during stratification, seed may become infected with bacteria and/or fungi. Some of the infected seed may decay during stratification. Decayed seed has a lower specific gravity (it will be lighter) than healthy seed. Growers can take advantage of this fact and “float” seed to remove those seeds that are decayed. It is not unusual to have up to 15% “floaters,” however, if a seedlot has more than 15% seed that floats, consider rejecting it. Some diseased seed will not float if decay is not advanced enough to affect specific gravity, so there are usually as many diseased seeds that remain as there are floaters. If seed is dug early enough, it can be floated more than once.

The fungi that infect seed are *Rhizoctonia*, *Pythium*, *Fusarium* and *Cylindrocarpon*. The presence of *Fusarium*, *Rhizoctonia* or *Cylindrocarpon* can be detected in seed that sinks by cutting the seed in half (Plate 30, page 93). Make cuts through the pore and along the groove that separates the two halves of the seed coat. If these fungi are present inside the seed, there will be a rusty discolouration (Plate 31, page 94). This could be anywhere within the seed and can range from a small spot to extensive discolouration.

When *Cylindrocarpon* or *Fusarium* have infected a seed, it can usually be seen on the exterior of the seed coat. Fruiting bodies called “sporodochia” can be seen

without magnification (Plate 32, page 94). They are usually 1 mm or less in diameter and will be white or pink to red. They are rimmed with a row of short “spines.” These fruiting bodies contain masses of conidia (spores). If these seeds are not culled from the seedlot, *Cylindrocarpon* and *Fusarium* conidia will be introduced into the new garden in vast numbers.

Seed rotted by *Pythium* usually has a “cheesy” interior (Plate 33, page 94).

Botrytis can also infect seeds and cause rot in storage. Seed decayed by *Botrytis* will float to the surface when the seeds are immersed in water. *Botrytis* seed infections can begin during depulping when seeds are left too long, either to rot the pulp or after mechanical depulping and before burial.

Seed can also be decayed by bacteria. Bacterial decay of ginseng seed usually causes the interior to liquefy into a milky or sometimes black fluid (Plate 34, page 94). When the seed is squeezed, the liquid will ooze out through the micropore (Plate 35, page 94). Seed decayed by bacteria has a sour odour. Healthy ginseng seed should have no odour.

Ginseng Chemistry

There is a range of biologically active chemicals in ginseng. These include ginsenosides, gypenosides, alkaloids, polypeptides and polysaccharides. Ginsenosides and polysaccharides have been evaluated in clinical trials. This publication does not make recommendations regarding the health benefits of ginseng.

Ginsenosides

The ginsenosides in ginseng are chemicals that belong to a group of compounds called saponins and fall into one of two categories: protopanaxadiols and protopanaxatriols. There have been 30 ginsenosides identified in ginseng. Oriental (Asian) ginseng (*Panax ginseng*) can be distinguished from North American ginseng (*Panax quinquefolius*) using ginsenoside profiles, because Asian ginseng contains ginsenoside Rf and North American ginseng does not. In clinical trials, the alleviation of the symptoms of Type II diabetes have been linked to ginsenosides in ginseng.

The overall ginsenoside content of ginseng roots varies, depending on the production system (see Table 4-1, *The Relationship of Production System and Total Ginsenosides by Weight in Ginseng Roots*, opposite page). See *Factors Affecting Root Quality*, on page 40, for a description of how production practices within the field cultivation system affect ginsenosides.

Table 4-1. The Relationship of Production System and Total Ginsenosides by Weight in Ginseng Roots

Root Source	% Total Ginsenosides by Weight
Wild ginseng	4.2
Woods-grown ginseng	4.4
Field-cultivated ginseng	3.8
Ginseng fibre roots	7.8

Research at the University of Guelph has shown that the ginsenoside profile is also affected by the production system (see Table 4-2, *The Relationship of Production System to the Amount of Specific Ginsenosides in Ginseng Roots*, this page).

Polysaccharides

Non-starch polysaccharides make up the fibre content of ginseng. The polysaccharide component of ginseng consists of sugars, uronic acids and lignin. Total polysaccharides range from 7.8%–9.9% of the root weight. In clinical trials, enhanced immunity to colds and flu have been linked to ginseng polysaccharides.

Testing for Ginsenosides

In ginseng, ginsenosides are formed by chemical processes that go on in the plant. These processes are a result of ginseng's genetic code, which is why there are differences between Asian ginseng and North American ginseng.

In chemical terms, ginsenosides are molecules. A molecule is a group of elements joined together in a specific arrangement.

The different ginsenosides all have a similar basic structure with slightly different attachments. These variations give each of the ginsenosides specific weights and shapes, giving them the property that allows them to be identified and quantified by the process of thin-layer chromatography.

Thin-layer chromatography is based on the principle that different molecules (such as ginsenosides) move at different rates up a thin layer of gel on a vertical glass plate when a drop of the test chemical is placed at the bottom of the plate. For example, in 10 min, ginsenoside Re might move up 5 cm, while ginsenoside Rc might move up 7.6 cm. The gel is also a chemical and provides resistance to this movement and is a factor in how things move up the plate.

Test chemicals such as ginsenosides must be dissolved in a suitable liquid that “pulls” the spots upward through the gel. The system works in the same way as dipping the tip of a paper towel in a puddle of water. This process is so specific that it can be used to identify what chemical is moving up the gel and calculate how much of it was in the original spot.

Each of the ginsenosides will eventually move to a specific spot in a given time. The spots can be measured by spot size and by the distance they move from the bottom of the gel on the glass plate. This placement is the “retention value” or R number. The plates are sprayed with a reactive chemical that turns colour, hence the term chromatography. The spots can be compared with known references so mixtures of ginsenosides can be identified.

Modern chromatography uses much more sophisticated tools than gel on a glass plate, but the principle is the same. High performance liquid chromatography (HPLC) injects a solution of the test chemical containing ginsenosides (one-millionth of a litre) into a gel column. Different ginsenosides move through the column at different rates, depending on the chemical they are dissolved in.

Ginsenosides can be detected with ultraviolet light electronically (because every molecule absorbs light energy at different wave lengths), and a computer analyzes the data. The result is a graph with peaks and valleys; each ginsenoside has a specific spot (in this case, wavelength) where it “peaks.” This is a very effective technique that can identify and quantify small amounts of ginsenosides. It is the current method of choice when testing for ginsenosides.

Table 4-2. The Relationship of Production System to the Amount of Specific Ginsenosides in Ginseng Roots

Root Source	% Specific Ginsenosides by Weight									
	Rg2	Rg3	Rg1	Rf	Re	Rd	Rc	Rb2	Rb1	Ro
wild	0.73	0.71	18.01	0	20.23	8.96	14.87	2.86	29.38	3.47
woods-grown	0.8	0.068	8.22	0	31.82	7.26	13.13	2.5	32.27	3.28
field-cultivated	1.97	1.76	4.38	0	35.29	12.38	14.92	2.12	20.9	6.35
field-cultivated root fibres	1.91	3.69	5.96	0	25.41	15.87	27.98	3.9	21.94	2.91

Variations arise when different techniques are used to extract the ginsenosides from the plant tissue or when different chemicals are used to flow through the gel. The structure of ginsenosides is affected by temperature and by the solvent used for extraction. If root is mashed up, placed in water (or alcohol) and heated, parts of some of the ginsenoside molecules will fall off, and the original ginsenoside won't show up in the chromatography test. Be aware that different labs may use different procedures for analyzing the constituents of a ginseng root. Results from two different labs cannot be compared unless they are using the same extraction procedures.

Roots

Harvesting Ginseng Roots

Ginseng roots are often harvested with a modified potato digger (Plate 36, page 94). Before harvesting the root, scrape the beds clean of plant refuse and straw. If plants have not senesced (died back), scraping the beds will pull up and injure roots. Senescence can be hastened by removing the shade and allowing the sun to kill back the foliage. This can take 4 days to 2 weeks, depending on the weather. Once the stems have dried, they will separate easily from the rhizome. After several passes over a garden with a root digger, most of the roots will be on the surface of the soil. Roots are usually collected by hand, but harvesting equipment that picks the root up is available. Take care to pick up the roots immediately after harvesting. Roots left on the soil surface for long periods of time can become infected with opportunistic soil fungi such as *Rhizopus*. These infections will go unnoticed until the root is removed from the kilns, and grey patches appear on the roots.

Factors Affecting Root Quality

Root Age

Ginsenoside Content

In the commercial production of ginseng, the total ginsenoside concentration in roots increases with plant age over the 4 years during which the ginseng is in the ground (see *Ginseng Chemistry*, on page 38). The most pronounced increase (about two-thirds) occurs with the ginsenosides Rb1, mRb1, and Re. Total ginsenoside content increases from about 3% in year 1 to about 8% in year 4. Ginsenoside levels do not increase indefinitely and appear to level off after year 6.

Starch and Sugar Content

Root age has little effect on the starch and sugar levels of ginseng. Sugar increases in concentration

over 4 years from 3% in the first year to 6% in the fourth. During this time, starch concentration shows a corresponding slight decrease from about 55% in the first year to about 49% in the fourth.

Root Size and Shape

Ginsenoside Content

No difference in the total ginsenoside content of roots weighing 2–8 g dry weight has been observed in research trials. The average fresh weight of a ginseng root at 3 years of age is about 20 g. A root weighing 20 g fresh will likely weigh 5–6 g dried. Roots lighter than 2 g contain slightly more total ginsenosides than larger roots. Prongs and fibres contain the highest concentrations. This is because ginsenosides appear to accumulate in the periderm, the outer surface layer of the root. The smaller the root, the greater the proportion of surface area.

Root shape (see *Ginsenosides and Root Shape*, on page 44) does not affect either the individual or total ginsenoside concentration.

Harvest Date

Ginsenoside Content

Total ginsenoside levels decline after mid-September and by November may decrease by about 14%. The individual ginsenosides Rb1, Rb2, Rc, Rd, mRd and gypenoside XVII decrease as the harvest date is delayed from mid-August until mid-November.

Starch and Sugar Content

In starchy roots such as ginseng, there is always a certain amount of conversion of starch to sugar. Starch concentration decreases as harvest date is delayed. The formation of sucrose accounts for about 80% of the starch loss. The other 20% results in the formation of other forms of carbohydrates, possibly polysaccharides. This characteristic increase in sugar concentration has been observed in potato and parsnip and serves to protect the root from freezing.

Root Colour

Root colour is slightly darker in roots harvested between mid-August and mid-September than in roots harvested later in the fall.

Dry Matter Content

Harvest date within a normal range does not affect the dry matter content of ginseng roots. Root moisture and dry matter levels do not change between August and November.

Conditioning Ginseng Roots

Harvested root is stored under cool, moist conditions in a refrigerated area for 2–6 weeks to "condition"

it (Plate 37, page 95) and is then washed (Plate 38, page 95) and dried on drying trays in forced air kilns. Ginseng loses about 70% of its fresh weight during drying.

Temperature

Optimal temperature for post-harvest conditioning appears to be 3°C–8°C. Research has shown that roots held at a constant temperature can remain alive at –5°C, while temperature fluctuation between –3°C and 20°C may cause roots to die. This emphasizes the importance of reliable temperature control.

Ginsenoside Content

Total ginsenoside content is reduced by about 7% when root is conditioned at –2°C. Conditioning temperatures between 3°C and 13°C do not affect the ginsenoside content.

Starch and Sugar Content

The greatest conversion of starch into sucrose occurs between 3°C and 8°C. Extreme conditioning temperatures of –2°C and 13°C decrease the conversion of starch into sucrose. Roots remain alive during the conditioning process. During post-harvest conditioning at 3°C–8°C, roots harvested in August, September and October show a decrease in starch concentration and an increase in sugar concentration during the first 30 days of conditioning. There is no further change in starch or sugar concentrations after 30 days. For roots harvested in November, most of the hydrolysis of starch into sugars has already occurred in the field, and additional low-temperature conditioning does not result in any further hydrolysis of starch.

Root Colour

Root colour is darkened significantly by exposure to –2°C. Slight darkening occurs at 13°C.

Dry Matter Content

At conditioning temperatures, there is a small dry-matter loss due to respiration of about 1.5% during the first 14–21 days. The dry matter content of fresh root is about 30% but it varies with age. One-year-old roots have a dry matter content of about 25%, while 4-year-old roots have a dry matter content of about 31%.

Root Appearance

The greatest impact of post-harvest, low-temperature conditioning prior to kiln drying appears to be moisture loss resulting in surface wrinkling, as well as darkening of the surface colour. Roots with a shrivelled and darkened exterior appearance are often preferred in the marketplace. After 40 days of low-temperature storage at 85%–90% relative humidity, roots can lose 27% of their original weight (25.5% moisture and

1.5% dry matter). Significant wrinkling does not occur until 20% moisture has been lost.

Length of Conditioning

The length of post-harvest conditioning affects sugar concentration in roots harvested in August, September and October but not in roots harvested in November. Maximum sugar concentration is reached after 30 days of conditioning except for roots harvested in November. Minimal differences in colour and a slight increase in ginsenoside level (of about 0.6%) occurs within 30 days.

Drying Ginseng Roots

After conditioning, ginseng roots are washed. Take care not to wash the roots too vigorously. Overwashing of ginseng roots results in a white surface colour that can reduce the value of the roots.

Place washed roots on trays (Plate 39, page 95) in forced air kilns (Plate 40, page 95) and dry to about 5%–8% moisture. Optimum drying temperature is 38°C.

The moisture content of dried roots is slightly higher when roots are not conditioned. Conditioned roots take slightly longer to dry. The average weight of a 3-year-old dried root is 5 g. After drying, sort and pack roots into cardboard barrels lined with plastic bags. They can be safely stored at room temperature up to 2 years. Properly dried ginseng root will have a light tan or creamy coloured interior (Plate 41, page 95).

Ginsenoside Content

Optimal drying temperatures for ginsenoside recovery appear to be 32°C–38°C. The concentration of malonyl ginsenosides decreases if drying temperatures are increased from 38°C–44°C. Total ginsenoside concentration can be reduced by 26% at a drying temperature of 44°C and by 17% at a drying temperature of 38°C compared to freeze-dried root. Only gypenoside XVII increases at the higher temperature (see *Ginseng Chemistry*, on page 38).

Starch and Sugar Content

Starch hydrolysis (the conversion of starch to sugar) occurs at all of the above temperatures during forced air drying of ginseng. More starch is converted to the sugar sucrose when ginseng is dried at 32°C or 38°C than at 44°C. Sucrose is the main sugar found in North American ginseng.

Root Colour

Internal root colour darkens as the drying temperature is increased from 32°C to 44°C. At 44°C, the root is darkened enough to significantly reduce its value.

Sanitation During Conditioning and Drying

If weather is wet at the time of harvest or if soil adheres to roots in the cooler, there is a chance that opportunistic fungi such as *Rhizopus* may invade the root tissue. *Rhizopus* infection is discussed in *Post-Harvest Diseases and Disorders*, this page. Because soil is a source of *Rhizopus* infection, take all possible measures to avoid soil contamination of rooms, fan blades and storage containers.

In the Coolers

Keep the floor as free of soil as possible. Before root is placed in the cooler, sanitize the floors with one of the sanitizing materials described in *Sanitation*, on page 64. It is preferable to use plastic containers to hold roots, as these can be adequately sanitized. Wooden containers such as bushel baskets can become contaminated through re-use and may be a source of root infection. Sanitize fan blades before use each year, as they can be another source of infection.

In the Kilns

Follow the same sanitizing procedures in the kilns as followed in the coolers. It is important to sanitize drying trays and fan blades before loading the kiln. Be sure any resulting fumes have dissipated before loading root into the kilns.

Post-Harvest Diseases and Disorders

Red Root (Varicose Disorder)

Occasionally, ginseng root will develop lengthwise red streaks along the root (Plate 42, page 95). These streaks may be numerous enough to give the root an overall red appearance. Close examination of the red streaks reveals that they are distinct (Plate 43, page 96) and occur primarily in the outer layer of the root interior (Plate 44, page 96).

Ginseng roots contain secretory ducts. Under certain environmental conditions, these ducts will become filled with phenolic compounds. As the root dries, these compounds turn red. This seems to be independent of the drying temperature. There has been no research indicating a connection with root nutrition, but there may be a connection with soil moisture stress early in the life of the plant.

Mouldy Root

Sometimes root decay will occur during drying. This appears to happen under very specific air temperature and humidity conditions. However, the exact conditions that promote disease in the kiln have not been researched. Sanitation and proper air circulation usually prevent these drying problems. *Rhizopus* and *Geotrichum* are two fungi associated with mouldy root in the kiln.

Rhizopus Rot

Rhizopus is a common fungus and can be found on many objects, in the soil and in air currents. It is one of the fungi that occurs on stale bread. If *Rhizopus* is present in the drying kiln, it may cause a rapid decay of ginseng roots during that period when both temperature and humidity are high. Affected roots will develop grey patches that will remain visible after drying is complete (Plate 45, page 96). Affected roots are unmarketable. The source of *Rhizopus* in drying kilns is most often dirty fan blades. Before ginseng is dried, check and clean all blades. Good sanitation procedures in the coolers and in the kilns will help to reduce the incidence of *Rhizopus*.

Geotrichum Mould

Geotrichum candidum is a soil fungus that can be found in most agricultural soils. It is only a problem on ginseng that is dried in faulty kilns or where large roots are packed too deeply on trays in the dryer. It is very important to ensure good air circulation when drying ginseng. If a kiln has areas where humidity persists, this fungus may develop. *Geotrichum* develops at temperatures around 37°C (Plate 46, page 96). It produces many conidia that are easily dislodged when handled and can cause lung irritation in humans. It has a distinctive, dirty-white "fuzzy" appearance and usually a sour odour. If this mould is found in a kiln, wear respirators when removing decayed root.

Grading Ginseng by Root Shape

Several factors affect the perceived quality of dried ginseng root in the marketplace. Among these is the shape of the root. Wholesale and retail markets may recognize as many as 20 root-shape categories. The traditional grading systems used by buyers and wholesalers separate dried roots into various levels of preference, mainly on the basis of shape.

Preferred roots are thick but relatively short. Wholesalers often prune portions of lateral root branches from dried roots to produce a more desirable shape.

Despite the importance of root shape in the marketing of the crop, little has been done to develop root shape classification schemes for *P. quinquefolius* grown in North America. An accessible standardized root grading system would be of value to producers of this crop as well as to researchers.

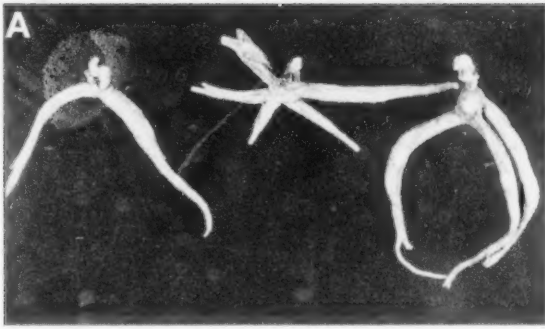


Figure 4-1. Spider-Grade Root
Taproot 0–2 cm in length

Spider-grade roots are considered less desirable and thus often have less market value. Roots in this grade are highly branched and may not possess a recognizable taproot.

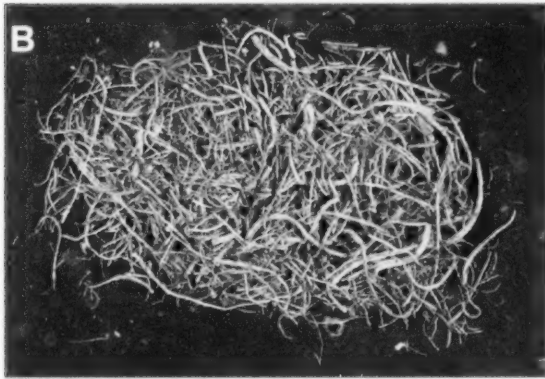


Figure 4-2. Fibre-Grade Root
Secondary or tertiary roots
with ≤ 2 mm in diameter

Fibre-grade roots include small secondary roots (1–2 mm in diameter). These small roots, as well as root debris broken off during handling associated with the root-drying process, are classified as “fibre”-grade material. They are frequently used in the preparation of teas and capsules.



Figure 4-3. Chunk-Grade Root
Taproots ≥ 2 cm in diameter and < 5 cm in length

Taproots provide 80% or more of the root dry weight. The chunk grade includes the valuable “bullet” and “bubble” grades.

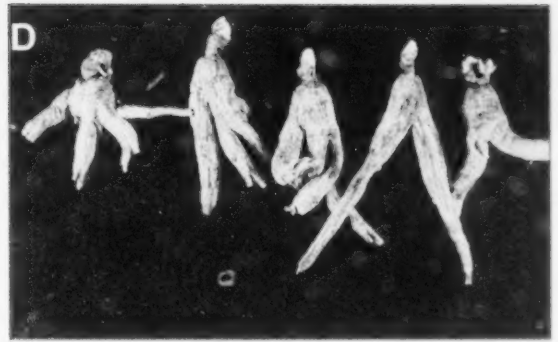


Figure 4-4. Forked-Grade Root
Taproots ≥ 2 cm in diameter and < 5 cm in length

Lateral root branches provide 50% or more of the root dry weight as visually estimated. The forked grade includes roots with a humanoid appearance, which is another desired shape.

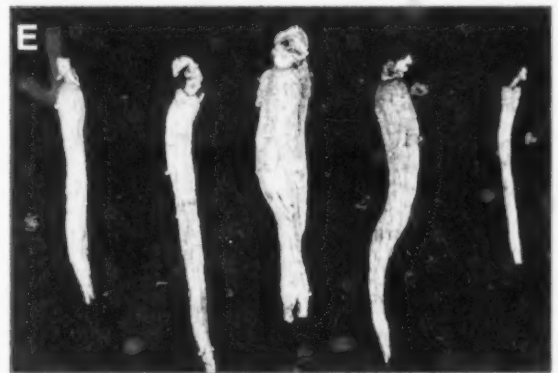


Figure 4-5. Pencil-Grade Root
Taproot ≥ 5 cm in length

Pencil (carrot) roots, including elongated roots with few, if any, lateral branches, are also less desirable.

Researchers at Agriculture and Agri-Food Canada, Delhi, Ontario, have developed a five-category classification system for dried roots that differentiates root shapes encountered in ginseng production and that has proven useful in separating desirable from undesirable root shapes (see Figures 4–1 through 4–5, on this page).

The method should be useful for researchers interested in comparing various agronomic treatments for their effects on ginseng growth and for growers who wish to visually assess the quality of their product prior to sale.

Root Shape Classification

Root shape categories are basically variations of five main root shapes that can be described, using terms common in the trade, such as spider, fibre, chunk, forked and pencil (carrot).

The relative contributions of root branches or the main taproot to total root dry weight are important factors in separating certain grades, in particular, the “chunk” and “forked” grades.

Ginsenosides and Root Shape

A study reported in the *Canadian Journal of Plant Science* compared root grades to concentrations of various ginsenosides. See *Ginseng Chemistry*, on page 38, for an explanation of the chemical components of ginseng.

Spider, chunk, forked and pencil root shape classes do not differ for any of the ginsenosides or ginsenoside-like materials quantified in this study.

The concentrations of Rc, Rb2, Rb3 and Rd were higher in the fibre grade. As fibre-grade material has a greater surface-to-volume ratio than other grades, these differences may reflect differences in the location of ginsenosides in the roots. Most ginsenosides are thought to reside in root epidermal tissue (the outer skin).

Root shape is one determinant in assessing root quality. Other factors such as taste, texture and moisture content also affect quality as perceived by the marketplace. Apart from differences observed between fibre-grade and other shape classes, there is no relationship between ginsenoside content and root shape in *P. quinquefolius*.

The information in this section is taken from research reported in the *Canadian Journal of Plant Science*, 2003. (Roy, R.C., Grohs, R., and Releeder, R.D. 2003. A method for the classification by shape of dried roots of ginseng (*Panax quinquefolius* L.). *Canadian Journal of Plant Science* 83(4):955–958).

CITES Requirements for Exporting Ginseng

What Is CITES?

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) classifies animals and plants into one of three appendices, depending on their severity of endangerment.

CITES began as the United Nations Environment Program in 1975 as a result of growing awareness that international trade was endangering more and more wild species everywhere on the planet. Today,

CITES is an international consensus on sustainable mutual management of natural resources that includes 175 member states (parties). A conference is held every 3 years by delegations from all the parties to decide on modifications to be made to the appendices, to evaluate progress in the restoration and conservation of species and to evaluate the needs of the different endangered species. The CITES Secretariat, based in Geneva, Switzerland, carries out these decisions.

How Does CITES Work?

CITES operates through an import/export permit system. Rules and regulations associated with CITES apply to the export of Canadian ginseng, which is listed under CITES in Appendix II. Appendix II plants are not considered threatened with extinction but may become so if their trade is not regulated. Appropriate permits are required for the international movement of Appendix II plants.

Any CITES-listed species imported into Canada, exported from Canada or attempted to be exported without the necessary permits is subject to seizure and forfeiture, and the importers/exporters are liable to prosecution.

CITES and the Export of Ginseng

The exportation of wild North American ginseng (*Panax quinquefolius*) is prohibited from Canada. Only cultivated ginseng may be authorized for export from Canada. CITES exports permits are also not issued for illegal material, such as roots collected in violation of the *Endangered Species Act* (see *American Ginseng in Ontario and the Endangered Species Act, 2007*, on page 30).

The exportation of cultivated North American ginseng (*Panax quinquefolius*) always requires a Canadian CITES export permit issued by the Canadian Wildlife Service. The requirement for CITES permits applies only to whole and sliced ginseng roots and parts of ginseng roots. CITES export permits may be single-use or multiple-use.

A CITES export permit is not required for exporting live ginseng plants, ginseng seeds and manufactured parts or derivatives, such as powders, pills, extracts, tonics, teas and confectionery.

The Canadian Wildlife Service may issue Multiple-Use Export Permits for Cultivated American Ginseng. These permits are restricted to ginseng exporters who frequently export ginseng shipments in a year and/or export these within short time frames.

Multiple-use export permits for ginseng are subject to strict conditions and procedures; protocol differs depending on whether they are for personal or commercial purposes. Photocopies of permits are no longer valid.

A multiple-use export permit for personal use may only be used to export shipments < 4.5 kg. Multiple-use export permits for personal use are accompanied by a specified number of sticker permits. Each sticker permit is individually numbered and should be used in sequential order. Sticker permits are comprised of three sheets: the first sheet is to be returned to the CITES Management Authority, the second sheet is for the permit holder's records and the third copy is the actual sticker. The quantity of the ginseng shipment and the country of import must be written on the top copy (the information will transfer to the other two sheets). The sticker should then be affixed directly to the ginseng shipment to accompany the package upon export. All unused stickers must be returned to the CITES Management Authority upon expiration of the permit.

Commercial multiple-use export permits may only be used to export ginseng shipments > 4.5 kg. A specified number of certified-true copies of the permit will be provided to the permit holder. Prior to export, the name, address and contact information of the consignee should be written on the permit, as well as the quantity and destination of the shipment. The shipment number and date of shipment should also be indicated in the appropriate box. A copy of the permit must be made once all the information is filled out and the copy should be sent to the CITES Management Authority. The certified-true permit accompanies the shipment to its destination. Every permit requires validation by a Canadian Customs Officer for each shipment exported prior to it leaving the country. Any unused certified-true permits should be returned to the CITES Management Authority upon expiration of the permit.

Contacting CITES

A CITES permit application form specifically for ginseng and goldenseal is available at:
www.cites.ca/pdf/application_panaxhydrastis.pdf.

Applications can be sent by one of the following methods (send application only once):

To:
 Management Authority
 Convention on International Trade in Endangered Species (CITES)

By mail:
 Canadian Wildlife Service
 Environment Canada
 Ottawa, Ontario K1A 0H3

By courier:
 Place Vincent Massey, Suite 306
 351 St-Joseph Boulevard
 Gatineau, Quebec J8Y 3Z5

By fax:
 819-953-6283 (applications exceeding 10 pages will not be accepted by fax)

The Canadian Wildlife Service can be contacted at:

Management Authority
 Convention on International Trade in Endangered Species (CITES)
 Canadian Wildlife Service
 Environment Canada
 Ottawa, Ontario K1A 0H3

Phone: 1-800-668-6767 (toll-free number)
 or 819-997-1840 (National Capital Region)
 Fax: 819-953-6283

5. Diseases, Pests and Disorders of Ginseng

Pests are the biggest challenge to ginseng cultivation in Ontario. Ginseng is susceptible to a wide range of insects, nematodes, diseases, weeds, and other problems, with soil-borne disease being the most economically important. Management of ginseng pests requires proper identification and knowledge of pest biology.

Diseases

It is important to understand the concept of “inoculum load” when dealing with ginseng diseases. Inoculum load is the amount of pathogen present in a ginseng garden. As disease progresses in a garden, the pathogen population builds up. The number of pathogen propagules (infective units) may become so overwhelming that normal control measures become ineffective. A fungus that is normally a moderate threat may become a serious threat when it multiplies in diseased tissue. As tissue rots and pathogen populations increase, the ability of a fungus to invade adjacent healthy tissue increases. When these situations arise in a garden, they are called “hot spots.” Once hot spots become established, it becomes increasingly difficult to control disease. It is far easier to prevent disease through vigilant cultural and sanitation practices than to deal with established, spreading disease.

Pythium Diseases of Ginseng

Pythium spp.

See Figure 5-1, *Life Cycle of Pythium on Ginseng*, next page.

The Fungus and Symptoms

Pythium is a soil fungus. Both *Pythium* and *Phytophthora* belong to the same group of fungi called “oomycetes” (oh-oh-MY-seats). *Phytophthora* and *Pythium* share a number of features: both produce swimming spores (zoospores) that are mobile in soil water; both produce “oogonia,” reproductive structures (like an egg) that are highly resistant to adverse conditions and can persist in the soil for a long time. There are additional structural and chemical features of this class of fungi that set them apart from other pathogens. This has meant that pest control products that control foliar diseases may not control *Pythium* and *Phytophthora*. The cultural practices that assist in

the control of these fungi are critical to the health of ginseng gardens.

Pythium is an opportunistic fungus. It can exist in the soil on organic matter and can attack seeds and seedlings (in the case of ginseng) as the opportunity arises. Because it can exist on soil organic matter, it is present in a wide variety of soils from season to season. It does not need ginseng to survive. *Pythium* can be found in most agricultural soils in Ontario.

When *Pythium* zoospores infect plant tissue, they form cysts that develop mycelium, which releases toxins and produces an enzyme that dissolves the parts of the cell that glues plant cells together. This kind of activity produces what is called a “soft” rot.

Pythium and Seeds

Ginseng seeds remain in the soil for many months between planting in the fall and germination in the spring. During this time, the seeds are susceptible to invasion by *Pythium*. When *Pythium* attacks seeds, the seed coat will not rot away, but the interior of the seed will become a curdled, “cheesy,” creamy-coloured mass (Plate 33, page 94). Eventually, the interior of the seed disappears, and only the seed coat is left. If seed is buried in the ground during stratification, *Pythium* can invade the seed before it is planted in the garden. This seed often floats, but some infections may not be well established and the disease is transferred to the new garden. See *Diseases of Ginseng Seeds*, on page 38.

Pythium and Seedlings

In seedling gardens, *Pythium* is part of the “damping-off” process. *Pythium* can infect young plants after they germinate and before they emerge through the soil surface. Affected plant tissue becomes dark and brown. Seedlings can also become infected after they emerge. Root tips, buds and the base of the stems can succumb to *Pythium* infection. This is often followed by the collapse and death of the entire seedling. Damping-off is a symptom (Plate 47, page 96) and can be caused by *Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium* or *Cylindrocarpus*. *Pythium* infections do not occur in the distinct circles that are typical of *Rhizoctonia*. *Pythium* is often distributed randomly throughout a garden and when conditions are right, many plants can be affected simultaneously.

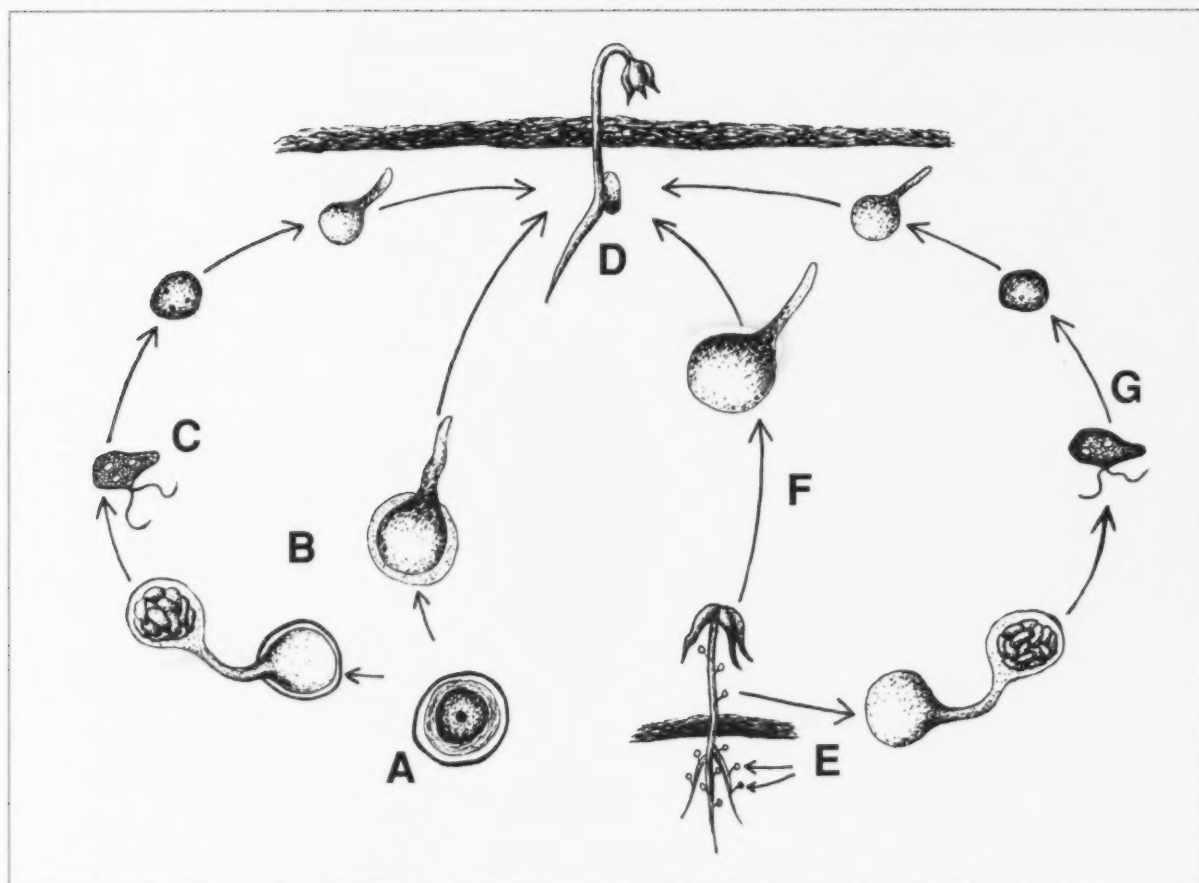


Figure 5-1. Life Cycle of *Pythium* on Ginseng

Winter: A. *Pythium* overwinters in the soil as oospores, resistant "egg-like" structures that can withstand adverse environmental conditions.

Spring/Summer: B. In warm, moderately wet conditions, mycelium (fungal threads) will grow directly from the oospore and infect plant tissue (B-D).

C. In cooler conditions, the oospore will form a sporangium containing many "zoospores," swimming spores that in turn germinate and infect plant tissue (B-C-D).

G. Before forming mycelium, zoospores encyst when they enter plant tissue. It is the advancing mycelium that directly causes decay by exuding macerating chemicals.

E. Many sporangia form on decaying plants and the infection cycle is repeated many times (E-G-D) (E-F-D).

***Pythium* and Older Gardens**

Pythium is a serious disease of seedlings and a sporadic disease of older plants. Older plants that are under stress at the time of emergence from adverse weather conditions may develop *Pythium* infections on the feeder roots (Plate 48, page 96) and the taproot tips (Plate 1, page 89). Infections on the emerging shoots can rot the tissue and prevent emergence. After emergence, the base of the stem and the bud may become infected (Plate 50, page 97). Infections of feeder roots will "prune" those roots and impair the uptake of water and essential nutrients (Plate 51, page 97). General symptoms that indicate that roots have been infected with *Pythium* include swollen tips on the feeder roots (Plate 48, page 96) and a

proliferation of feeder roots (Plate 52, page 97) as the plant tries to overcome root pruning.

The pattern of disease is an indicator of how *Pythium* got into a garden. If *Pythium* is present in the soil in garden beds, damping-off usually occurs in patches that are roughly circular. If it is introduced on seed from the seedbox, single plants will "go down" wherever *Pythium*-infested seed is present. In heavily seeded gardens, surrounding roots may become infected.

Factors Promoting Disease

Like *Phytophthora*, this fungus has swimming zoospores and is more active under wet conditions. Gardens where the surface water drains slowly or

where water pools are more likely to show signs of damping-off or root decay. *Pythium* infections can occur under drier conditions than *Phytophthora*.

Seedboxes can harbour *Pythium*, and seeds can become infected where surface runoff from older gardens flows over the buried seeds. If ginseng plant refuse is present uphill from a seedbox, contamination is very likely.

Another factor influencing the disease cycle of *Pythium* is contamination of the beds with unfumigated soil. Poor fumigation or movement of unfumigated soil will introduce *Pythium* into the new seedbed. Because this fungus is present in virtually all soils in this region, it can be introduced with unfumigated soil from areas below the fumigation zone. After fumigation, the balance of soil microbes is disturbed. Any fungi that are introduced into fumigated soil will have none of the checks and balances exerted by normal soil microflora and microfauna. This allows introduced fungi to grow and attack seeds and seedlings with ease. Do not assume that fumigated soil will continue to be *Pythium*-free over time. While fumigation reduces the *Pythium* population in the soil, there are many ways that soil can become recolonized. *Pythium* can enter a garden on blowing soil, in water runoff and on machinery and boots. Recolonization occurs to some extent about 3 months after fumigation.

Disease Management Practices

Cultural

Bed Formation

The single most important management practice is the care taken when forming beds. Fumigate deeply enough to allow bed formation in the fumigated zone.

Throughout the ginseng-growing areas of Ontario, unfumigated soil can be assumed to be contaminated with *Pythium*.

Water Management

Elimination of standing water and facilitation of directed water flow, away from gardens, is essential.

Good Sanitation

Even after good fumigation and proper bed formation, *Pythium* can be introduced on machinery and boots or shoes from older gardens. It is important to work in seedling gardens first and to insure that workers wear plastic booties or decontaminate their boots or shoes. Soil can blow into gardens and filter through the straw to contaminate beds. Gardens can be somewhat protected by a rye strip that breaks the force of the wind. A metre-wide strip of rye or other fast-growing grain situated against the prevailing winds can act as a barrier to the introduction of *Pythium* on particles of soil. Such strips may need to be managed for cutworm control in the spring. Any good windbreak will suffice, but take care not to stifle the air movement to the point of creating an environment for foliar disease.

Using Fungicides

The first line of defence is fumigation. See *Fumigation*, on page 34, for more information and Table 6-2, *Preplant Fumigation of Ginseng in Ontario*, on page 75, for fumigant recommendations. Researchers are exploring alternatives to the use of fumigation. See Table 6-1, *Ginseng Seed Treatments*, on page 75, for recommendations on seed treatments to control *Pythium* in ginseng.

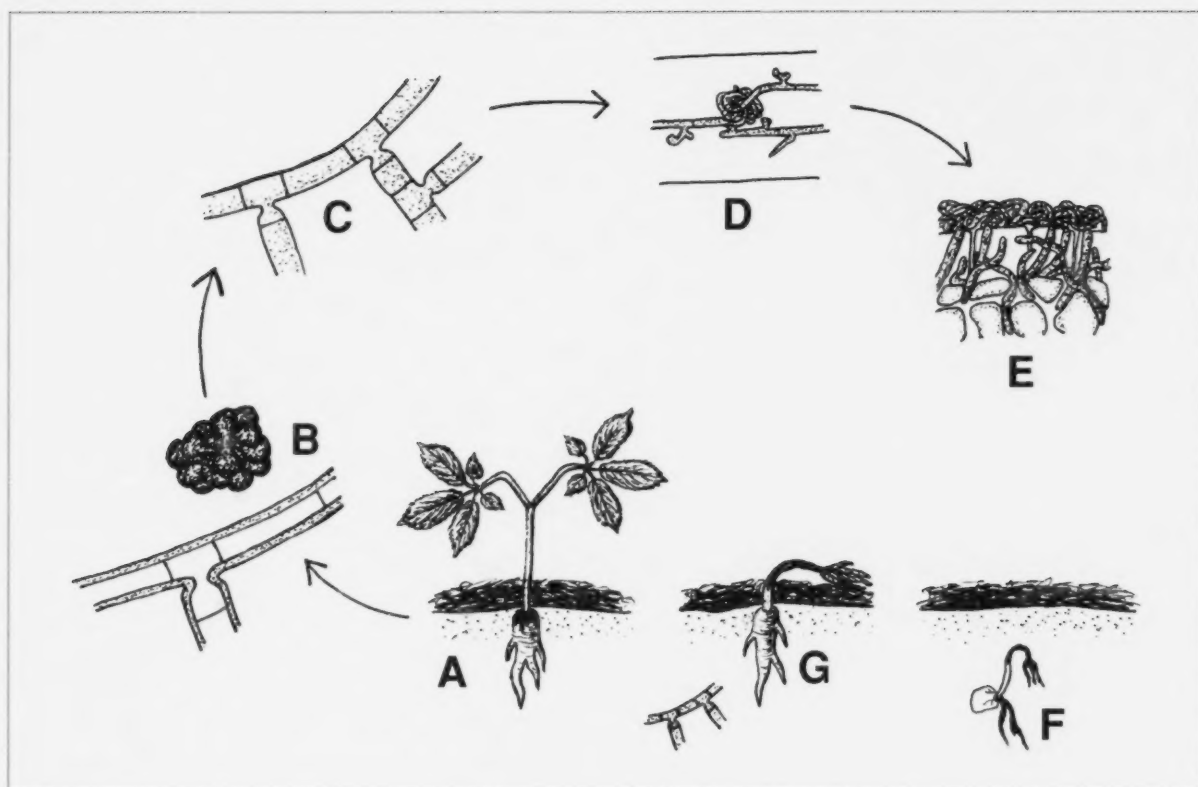


Figure 5-2. Life Cycle of *Rhizoctonia* on Ginseng

Winter: A. *Rhizoctonia* hyphae (mycelium) can remain alive through the winter months in infected ginseng roots.

B. In the soil, *Rhizoctonia* sclerotia, a compact mass of resistant cells, can tolerate adverse environmental conditions.

Spring/Summer/Fall: C. When conditions are appropriate, mycelium will grow from the sclerotia and infect plant tissue in its path.

D. Runner hyphae extend along the root surface and eventually form an infection cushion.

E. The infection cushion sends hyphae to penetrate the root and cause decay.

F. *Rhizoctonia* can infect ginseng roots before emergence.

G. Stems can also be infected.

Rhizoctonia Diseases of Ginseng

Rhizoctonia solani

See Figure 5-2, *Life Cycle of Rhizoctonia on Ginseng*, this page.

The Fungus and Symptoms

Rhizoctonia solani is a soil pathogen. Unlike many other fungi, it does not usually produce spores. It grows through the soil vegetatively as mycelium (the mass of hyphae that make up the body of a fungus). When it encounters susceptible plant tissue, it forms a compact mass called an infection cushion and proceeds to penetrate the host. Once inside the host, it grows rapidly. Under adverse environmental conditions it may form small sclerotia (clumps of dark-walled cells). It can also form "runner hyphae" (hyphae are the individual threads that make up the mycelium) that criss-cross the root surface in search of a place to establish a new infection cushion. Using the energy from its host, the

fungus can travel to and infect adjacent roots within several centimetres of the diseased root. As it moves out from its original focal point, circular areas of disease develop in infected gardens.

Rhizoctonia is active under specific aeration conditions that usually occur near the soil surface, or even between the soil and straw mulch. However, under certain conditions *Rhizoctonia* may occur deeper in the soil. Infection occurs on the crown or bud and on the stem between the straw and the soil (Plate 53, page 97) (rhizoctonia crown rot, bud rot, rhizoctonia stem canker).

Rhizoctonia infection usually results in a rusty or darkened discolouration of the affected tissue (Plate 54, page 97). Rhizoctonia can appear as a dry, corky rot that does not penetrate the root tissue deeply. Roots damaged by rhizoctonia are susceptible

to invasion by bacterial rots, nematodes and small insects. Weakly pathogenic strains of *Cylindrocarpon destructans* can use root tissue damaged by rhizoctonia as a means to establish infection. When rhizoctonia itself may be superficial on the root, the secondary invaders may cause increased damage. Rhizoctonia is not a cause of rusty root of ginseng, but its symptoms can appear similar (see *Rusty-Root and Rust Spot of Ginseng*, on page 61).

Rhizoctonia is primarily a pathogen of young roots. Seedling gardens and 2-year-old gardens are particularly susceptible. Plant emergence often occurs under less than ideal environmental conditions, and this added stress on the developing plant predisposes it to infection. Infection can occur at any time after seed cracking. *Rhizoctonia* can rot seed, prevent emergence by infection of the new root or shoot before it reaches the soil surface or topple seedlings with stem canker shortly after emergence. The toppling of seedlings is called "damping-off." Older roots are seldom attacked by this fungus as it is unable to penetrate the older, tougher cell walls. This toughness is due to the incorporation of calcium into the cell walls over time. Older plants under enough stress from adverse environmental conditions can become infected with *Rhizoctonia* (Plate 55, page 98), but it is uncommon.

The formation of rust on ginseng roots can be a response to a number of irritants. *Rhizoctonia*, *Fusarium* and *Cylindrocarpon* typically cause rusty lesions.

Factors Promoting Disease

There are two strains of *Rhizoctonia* in Ontario that attack ginseng. One strain prefers the cool, damp soil in early spring and will attack plants at or shortly after emergence (Plate 56, page 98). This strain, which can tolerate temperatures at or below freezing, can be active during the fall and into the winter. The other strain prefers warmer, dryer conditions and can be active in the summer months. The summer strain causes symptoms that resemble those of infection by *Fusarium*. Since the fungus travels vegetatively (by

means of mycelial growth) through the soil from plant to plant, gardens with a high plant density will show a more extensive spread of the disease. This type of movement of the fungus results in "circles" of missing plants (Plate 57, page 98). *Rhizoctonia* is one of the fastest-growing fungi.

High nitrogen levels that promote rapid plant development will leave roots and stems susceptible for longer periods of time. Growth that is too rapid does not allow plants to harden off quickly.

Disease Management Practices

Cultural

The fungal threads of *Rhizoctonia* can cling to soil particles. Movement of this soil into gardens can spread the disease. Soil can move on wind, water, machinery and the boots of people who pass through the garden. Do not situate new gardens where they will receive runoff from existing gardens or vegetable fields. Have workers and machinery move from new gardens to older gardens, never the reverse. Take care not to introduce unfumigated soil onto beds as they are formed. See *Factors Promoting Disease*, on page 48, for a discussion of *Pythium* and fumigation.

The sooner gardens warm up and dry up in the spring, the less the risk of *Rhizoctonia* infection. It is common for growers to seed a "nurse crop" in newly seeded gardens in the fall over the straw mulch. This "nurse" crop is usually rye or a cereal such as oat that will winter-kill. It is sown at the rate of 180–454 L/ha (2–5 bu/acre). The nurse crop serves to anchor the straw through winter winds, and the roots open channels that assist drainage and aeration of the soil in the beds. This can assist in warming the soil in the spring.

Using Fungicides

See Table 6–6, *Disease Control Recommendations for Ginseng in Ontario*, on page 77, for recommendations to control *Rhizoctonia* in ginseng.

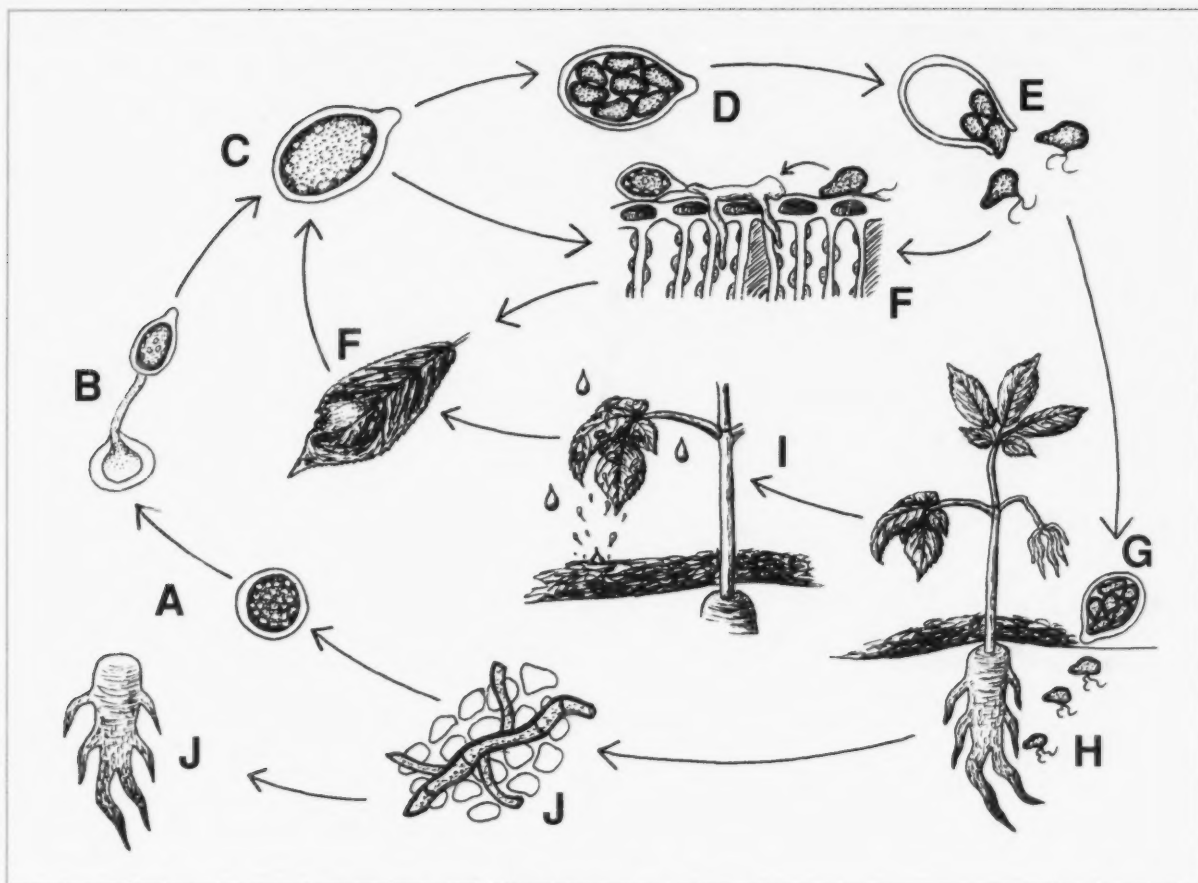


Figure 5-3. Life Cycle of *Phytophthora* on Ginseng

Winter: A. *Phytophthora* can survive the winter as oospores in the soil and as mycelium and oospores in infected roots.
Summer: J. When soil temperatures climb above 6°C, the mycelium will move throughout the soil in search of root tissue.
 B. The oospores will form sporangia.
 C./D. The sporangia will differentiate into many zoospores (D), each capable of becoming an infective unit (E, H).
 F. When sporangia form on leaves, they can separate from the main body of the fungus and blow on the wind to infect other leaves (I) or drop on the soil to infect roots (G, H).

Phytophthora Root Rot and Blight of Ginseng

Phytophthora cactorum

See Figure 5-3, *Life Cycle of Phytophthora on Ginseng*, this page.

The Fungus and Symptoms

Phytophthora root rot and blight is caused by the fungus *Phytophthora cactorum*. This fungus can attack a number of fruit and vegetable crops. It is a relative of the fungus that causes late blight in potato. *Phytophthora* is a soil-borne fungus and belongs to a group of water-loving fungi called oomycetes. This fungus can attack both the roots and the foliage of ginseng. The root rot phase of the disease is a leading cause of economic loss. The foliar phase of the disease

can spread geographically very rapidly and can result in increased soil infestations.

The fungus can be present in the soil in the form of mycelium (fungal threads) or oospores (the resting spores of *Phytophthora*). It can infect plant roots at temperatures above 6°C. In addition to oospores, the fungus produces another reproductive organ called a sporangium. The sporangium is a sac that can arise from mycelium or oospores. It contains many small swimming spores called zoospores, and when released, each zoospore is an infective unit. In the soil, sporangia will form on the surface of infected roots. In the case of foliar blight, sporangia will form on the surface of the leaves and can travel many kilometres on air currents. This gives the fungus great reproductive

and infective power. *Phytophthora* disease of ginseng is explosive. Once present in a garden, it becomes a constant threat. If environmental conditions favour the fungus, severe losses can occur rapidly.

Roots rotted by *phytophthora* have a "typical" pinkish-brown appearance (Plate 58, page 98). The interior of the root becomes cheesy (Plate 59, page 98) and when squeezed, a clear liquid oozes out. *Phytophthora* root rot causes a distinctive sour odour. Foliar symptoms of the root rot include purpling of the leaves (Plate 60, page 98). In a 3-year-old plant, one leaf may wilt while the other 2 leaves remain firm (Plate 61, page 99). The foliar blight causes different leaf symptoms. Foliar *phytophthora* begins as darkened, water-soaked areas of the leaf, usually at the tip or edge (Plate 62, page 99). Affected leaves droop and become watery and black (Plate 63, page 99).

Splashing water can carry zoospores, sporangia and even soil containing mycelium onto the leaves. If sufficient moisture is present, the fungus will rapidly grow into the leaf tissue. The leaf blight phase of the disease spreads rapidly throughout the garden and into other gardens downwind of infections. Sporangia from leaf lesions drop onto the soil and begin invading the roots. The fungus overwinters as oospores or as mycelium in diseased plant tissue and as oospores in the soil.

Factors Promoting Disease

Phytophthora is a water-loving fungus. Disease is most prevalent where soil moisture is above 60% field capacity or where there is water pooling in the garden. Areas of *Phytophthora* infection can often be found surrounding a leaky irrigation sprinkler (Plate 64, page 99). Because the fungus can be active at temperatures as low as 6°C, roots are vulnerable early in the spring and throughout the growing season.

The movement of machinery and people through standing water can splash the fungus up onto the beds and onto leaves. Rain can splash zoospores and sporangia up to 1 m. Excessive fertilization that results in a dense leaf canopy will create ideal humid conditions for the development of leaf lesions.

Disease Management Practices

Cultural

Management of *phytophthora* begins with site selection. See *Site Selection*, on page 31. Before planting ginseng, a topographic analysis is needed. Evaluate land for surface runoff patterns and low areas where water can pool or soil remains wet for long

periods of time. Assess sub-surface drainage either by a soil profile or by using a soil probe. Tiling is a good means of removing excess water from the root zone. Orient new beds to facilitate movement of surface water out of gardens. Do not situate new gardens where runoff from existing gardens is likely to flow.

Once the site is chosen and beds are formed, grade the garden. Trenches should be above the level of surrounding soil. It may be necessary to dig a perimeter trench to promote rapid water movement. It may also be necessary to direct surface water away from the garden area to an area where pooling is more appropriate. Consider subsoiling the trenches where wet areas persist.

In low areas where water can pool in trenches, partly fill the trenches with bark chips or gravel to avoid splashing. Stay out of gardens immediately after a rain. See *Water Management*, on page 31.

Use equipment in younger gardens first, wash it off before entering another garden and use it in older gardens last. Have people moving through the garden wear disposable plastic "booties" and change them between gardens. The impact of equipment on dispersal of this disease cannot be stressed enough. A single focal point of disease can translate into disease along every driveway in a matter of weeks, when equipment drags infected soil and water throughout the garden (Plate 65, page 99).

Using Fungicides

Preventive measures are the only effective means of managing *phytophthora* in ginseng gardens once the fungus is present. Use an integrated approach that combines more than one effective product from different chemical families. Good resistance management practices are imperative. Repeated use of products with a potential for resistance can result in the development of resistant strains of *Phytophthora*. See *Fungicide Resistance*, on page 62. See Table 6–6, *Disease Control Recommendations for Ginseng in Ontario*, on page 77, for control recommendations for *phytophthora* diseases of ginseng.

Spray coverage is important in any protective program. Make sure the sprayer is reaching all plant parts. Avoid plant stress due to the development of other ginseng diseases. Never use rates of disease control products or suggested water volumes lower than those recommended on the label.

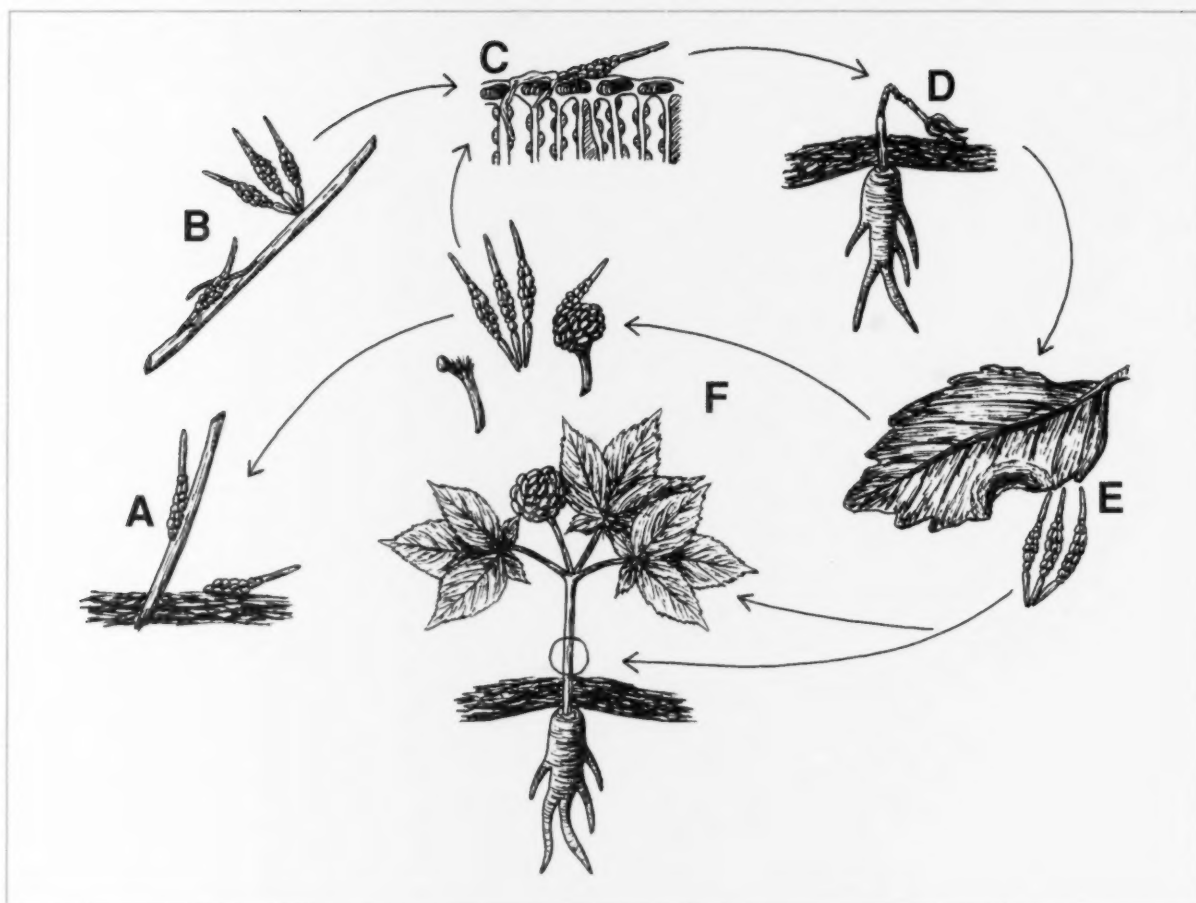


Figure 5-4. Life Cycle of *Alternaria* on Ginseng

Winter: A. *Alternaria* overwinters on ginseng refuse in the straw. It is especially abundant on old stems.

Spring/Summer: B. When conditions are right, the overwintering conidia germinate and penetrate plant tissue. Early-season infections in a garden are almost always on plants adjacent to old stems.

C. When conidia land on the plant surface, they germinate and penetrate the plant cells.

D. On stems, this causes a dry decay, and the plant topples.

E. On leaves, this causes a dry, tan lesion (area of decay) with a yellow halo.

F. Many conidia are produced on the lesions on leaves and stems and they can infect other plants in the garden as well as other gardens.

Alternaria Diseases of Ginseng

Alternaria panax

See Figure 5-4, *Life Cycle of Alternaria on Ginseng*, this page.

The Fungus and Symptoms

Alternaria diseases of ginseng are caused by the fungus *Alternaria panax*. There are many *Alternaria* species infecting many horticultural crops. Some species, such as *A. alternata*, have a very broad host range, but species such as *A. panax* attack a narrow range of host plants. *Alternaria* spores are present everywhere. They move about on air currents. *Alternaria panax* can be found throughout the ginseng-producing areas of the

world. Spores can be identified under a microscope by their distinctive shape (like segmented bowling pins with very long beaks).

In ginseng gardens, most *Alternaria* infections begin on stems early in the season. The fungus requires a definite period of humidity to cause infection. The length of the humid period varies with temperature. In ginseng gardens, once the plant canopy opens, the stems are sheltered by the leaves and a humid microclimate results, even in relatively dry weather. The first signs of stem infection are light or tan-coloured areas on the stem above the mulch. These areas soon become dry and brittle. As infection

proceeds, they become covered with a “sooty” layer of dark spores. A sooty residue will remain on a finger that has been rubbed along the dark portion of the lesion. Stem lesions resulting from *alternaria* usually cause the stem to buckle at the lesion and topple at a sharp angle (Plate 66, page 99). Stem lesions caused by *rhizoctonia* are not as brittle, and the stems bend in an arc, until the stem collapses. Another difference that aids in distinguishing between the two types of stem lesions is in their placement on the stem. *Alternaria* tends to be above the mulch layer while *rhizoctonia* is lower on the stem, either within the straw layer or just above the soil. (Plate 67, page 100).

Foliar symptoms of *alternaria* are usually distinctive. Typical lesions consist of a dry, tan central area surrounded by concentric dark and light areas and ultimately surrounded by a chlorotic “halo” (Plate 68, page 100). The dark areas are where the spores are formed. Lesions are circular or roughly angled in a circle. Severe infections on the peduncles, especially at the leaf axil, can cause defoliation. The peduncles are the short “stems” that hold the leaves and flower head. Unchecked, *alternaria* can defoliate an entire garden in less than a week if weather conditions are conducive to disease (Plate 69, page 100).

Atypical lesions can occur under extremely hot, humid conditions. In hot weather, the lesions may be dark brown or black and have a “greasy” appearance. Close examination will still reveal the concentric circles of sporulation. On seedlings in hot weather, stem lesions can cause the stem to become almost black and collapse. This results in leaf wilting and an appearance similar to damping-off.

Once established in a garden, spores will spread to developing seed heads. Berries on infected heads will become dark and shrivelled (Plate 14, page 91), eventually, dropping off the plant.

The fungus overwinters on the straw and on plant debris. Spores are formed in the spring and move on air currents throughout the garden.

Factors Promoting Disease

If *Alternaria* is present in a garden, spores will be present on plant debris throughout the winter. This is especially true of old stems. It is not unusual after the

canopy opens in the spring to find a group of plants with foliar lesions surrounding a stem still standing from last year. Plant debris is the most frequent source of spring infections in ginseng gardens.

Because the disease requires humidity to become established, a lush plant canopy promotes the development and spread of stem and foliar lesions. Gardens located in areas of “dead air” next to woodlots are more likely to develop hot spots. Later in the season, spores are blown into gardens from other infected gardens and from any nearby host plants.

Gardens with a low pH will be more severely affected by *alternaria*. The disease is more common on senescing plant tissue. As the season progresses and plants become more stressed, their susceptibility to disease increases. Gardens stressed by poor fertility, fertilizer injury, air pollution and mechanical stresses such as hail or drought will be more likely to develop disease.

Disease Management Practices

Cultural

Locate gardens where air can move freely. If side shades are erected, they should not completely restrict air movement. “Vent” large gardens by raising the lath or cloth at intervals to allow heated air to escape. All practices that reduce humidity will help prevent infections.

Before planting, soil pH should be between 6 and 6.5. Low pH predisposes ginseng to *Alternaria* infection.

Plant density can affect the development of disease. High seeding rates or fertility practices that promote lush foliage create an environment conducive to disease. Ginseng self-thins to about 80 plants/m² after 3 years. High seeding rates not only affect the microclimate in the leaf canopy but lead to smaller, thinner roots.

Using Fungicides

To be effective agents in the prevention of *alternaria*, fungicides must cover the stem and seed heads as well as the upper and lower leaf surfaces. See Table 6–6, *Disease Control Recommendations for Ginseng in Ontario*, on page 77, for the control recommendations for *alternaria* diseases of ginseng.

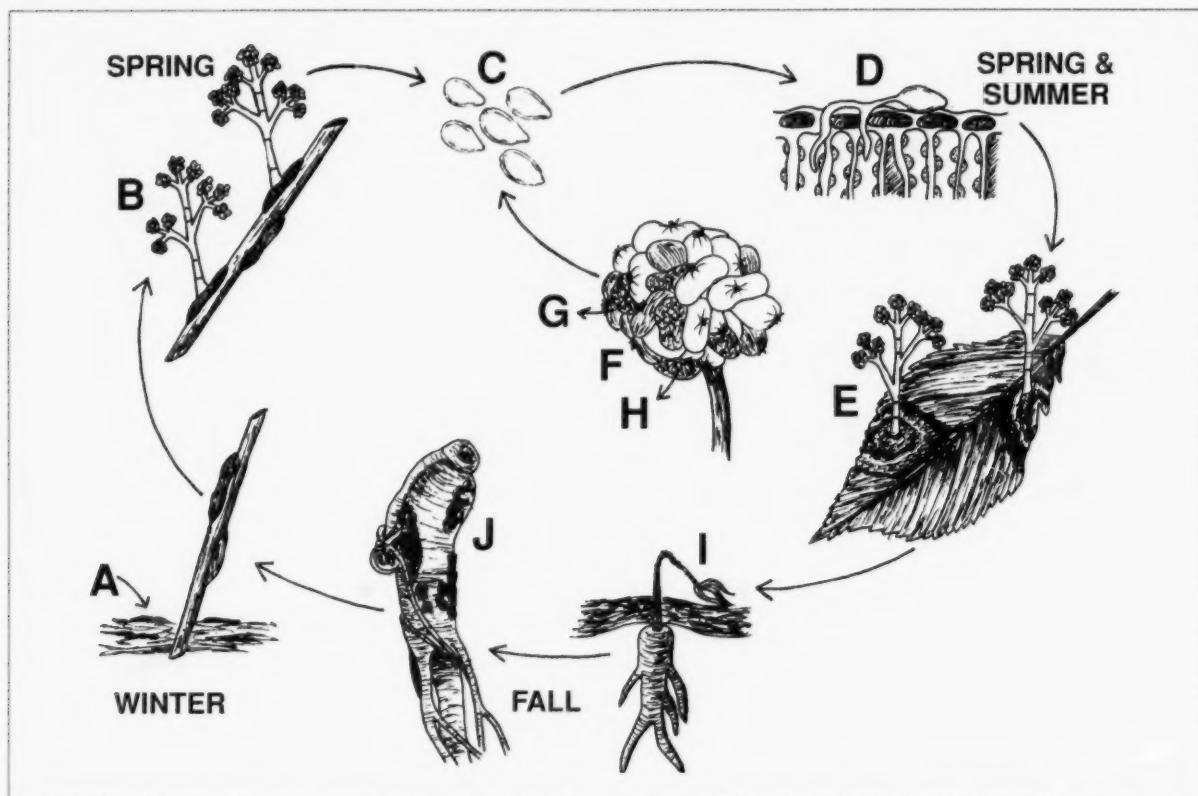


Figure 5-5. Life Cycle of *Botrytis* on Ginseng

Winter: A. *Botrytis* overwinters on the straw and on ginseng refuse as sclerotia — dark, tough bodies that can withstand adverse conditions.

Spring/Summer: B. When conditions are right, the sclerotia germinate, forming many conidia (C).

C. When conidia land on damaged plant tissue, they germinate and infect the cells. As lesions develop, they produce many conidia (E), and these are widely dispersed by the wind.

I. The lower stems of older plants can become infected with *Botrytis* when the canopy is lush, because relative humidity beneath the leaves remains very high.

Late Summer: F, G, H. In late summer, conidia infect the berries. Dying petals act as a food source for *Botrytis* and provide the energy to infect berries. If the flower head has been burnt by foliar fertilizer or damaged by sand or wind, the petioles can become infected as well.

Botrytis Blight of Ginseng

Botrytis cinerea

See Figure 5-5, *Life Cycle of Botrytis on Ginseng*, this page.

The Fungus and Symptoms

Botrytis blight of ginseng is caused by the fungus *Botrytis cinerea*. This fungus is a pathogen of many fruit and vegetable crops and causes the “grey mould” rot that is common to grapes, strawberries, greenhouse floral crops and many vegetables. *Botrytis* is most active between 18°C and 23°C. It can infect all parts of the plant, including the roots.

It frequently becomes established on plants toward the end of the flowering period. The fungus infects

the dying tissue of spent petals. It does not generally invade healthy, growing tissue but when it builds up enough mass on the dying petals, it is able to penetrate any tissue that it contacts. This ability to invade dead and dying tissue makes it particularly threatening to ginseng. *Botrytis* spores that lodge in the straw can germinate and develop “sclerotia” — hard, black bodies that can survive winter temperatures and adverse conditions. These sclerotia resemble small mouse droppings. When weather conditions are appropriate, the sclerotia germinate, resulting in many spores being produced and released (Plate 70, page 100).

Seed heads that become infected will produce a mass of “fuzzy” grey conidia (spores) (Plate 16, page 91).

Infected berries will turn purplish and shrivel (Plate 15, page 91). As the berries decay, they, too, will produce many conidia. As the fungus decays infected tissue, it develops the ability to invade adjacent healthy tissue. As one leaf decays and collapses onto another, the other becomes infected (Plate 71, page 100). This chain reaction of infection creates hot spots in a garden. During periods of high humidity, many conidia are released from "hot spots" to form new infection areas.

Leaf symptoms usually begin at the tip or leaf edge (Plate 72, page 100). Sometimes, if there has been mechanical damage, they will begin in the middle of the leaf. Infected leaf tissue turns pale, then tan, then "glassy." The rot is soft, and affected areas are quite wilted.

Stem rot also produces a soft lesion, unlike the brittle lesion caused by *alternaria* or the dry, stringy lesion caused by *rhizoctonia*. Infected stem tissue becomes soft, tan-coloured and eventually covered with a mass of grey mycelium and conidia (Plate 73, page 101).

Because *Botrytis* conidia are virtually everywhere, ginseng growers should assume that gardens will become infected whenever mechanical damage occurs. Hail, frost, tractor abrasion, sandblasting and deflowering all cause some degree of mechanical damage. Gardens damaged by early spring frosts are particularly vulnerable to *Botrytis* infection. Frost or freezing damage followed by warm, humid weather will result in a rapid rot of affected plant parts (Plate 73, page 101).

Damping-off of seedlings can occur in a humid season when temperatures are between 18°C and 23°C, especially after sandblasting. In these cases, the root is usually invaded and completely disappears. Outside this temperature range, damage will still occur but it will progress more slowly. *Botrytis* damage is seldom seen in very hot conditions.

Although not traditionally considered a root-rotting fungus, lower stem infections can move into roots and cause decay. *Botrytis* root infections may be associated with the reduced plant stand in ginseng gardens over time (Plate 74, page 101).

Factors Promoting Disease

Anything that causes mechanical damage to the leaf will predispose that leaf to infection by *Botrytis*. In Ontario, sandblasting that occurs early in the season can wound leaves and open them to infection. These infections occur at the edge of gardens. Mechanical injury can also occur from fallen shade, hail and the movement of machinery and people through the garden. Leaf injury

from fertilizers or pesticides can also precede infection. Gardens are especially susceptible after flowering. Ginseng flowers over a 4–6-week period, and infection can occur any time after the first flowers senesce. Infected petals can drop onto leaves or other flower heads, continuing the disease cycle.

Temperatures below 23°C coupled with high humidity will promote rapid disease. Humidity remains high within the plant canopy even when the outer surface of the leaves appears dry. Sclerotia on the straw, dropping infected petals and falling conidia will easily infect lower stem tissue. A dense plant canopy will maintain high humidity for extended periods of time. There is higher likelihood of infected leaves contacting healthy leaves when the canopy is dense.

There will be masses of spores produced in the spring where sclerotia have formed on the straw. Because so many different plants are affected by *botrytis*, it is likely that conidia will lodge in the straw sometime during the season, even in an apparently disease-free garden.

Disease Management Practices

Cultural

Removal of decaying plant debris will reduce the presence of *Botrytis* but not eliminate it. Ginseng tends to thin out to about 80–100 plants/m² after 3 years. Seeding rates that result in plant stands higher than this will promote a dense, humid environment within the canopy. Fertility practices that result in lush canopy development will also result in high humidity. This within-canopy humidity promotes *Botrytis* rot at the base of the stem just above and within the straw mulch.

Guards on machinery that prevent leaf abrasion will lessen disease. Caution workers to move through the garden with care.

A 1-m rye strip around the perimeter of the garden will help prevent sandblasting.

Using Fungicides

See Table 6–6, *Disease Control Recommendations for Ginseng in Ontario*, on page 77, for information on control of *botrytis*. Timing of *botrytis* controls should coincide with periods of susceptibility.

Fusarium Diseases of Ginseng

***Fusarium* spp.**

The Fungus and Symptoms

Fusarium is a common soil fungus found on a wide range of crops. It is widely distributed, and species of *Fusarium* can be found in most agricultural soils. In

the past, *Fusarium* was considered a minor problem in ginseng, linked mostly with stratification of seed in the soil, however it has become an increasing problem in Ontario ginseng production over the past several years. Numerous species of *Fusarium* have been found in association with ginseng, including *F. solani*, *F. equiseti*, *F. avenaceum* and *F. oxysporum*.

On ginseng, *Fusarium* is predominantly a saprophyte, living on dead and decaying tissues, but occasionally it can become an opportunistic pathogen, similar to *Pythium*, existing in the soil and attacking roots when the opportunity arises. *Fusarium* can enter ginseng roots through wounds or by attacking plants already stressed from moisture or nutrient deficiencies, or from infection by other diseases such as pythium or phytophthora. *Fusarium* has been found on floral parts, berries and seed; it is suspected that seedborne spores spread this disease in ginseng. Researchers have also isolated *Fusarium* from cereal straw used on gardens, suggesting that contamination can occur through the straw mulch. Often, when mulch is contaminated with *Fusarium*, white mats of fungus can be observed growing in the straw.

Fusarium can attack both feeder roots and the main tap root. When feeder roots are affected, the fungus interferes with the uptake of water and nutrients. Roots affected in this way become dehydrated, appearing wrinkled and pliable, with an absence of feeder roots. This has been observed most commonly in 2-year gardens. When the tap root is infected, rusty lesions may be observed on the root surface. The importance of *Fusarium* as a cause of rusty root is not fully understood (see *Rusty-Root and Rust Spot of Ginseng*, on page 61). Above-ground parts of ginseng plants infected by *Fusarium* will show signs of nutrient deficiency, including wilting and drooping below the junction of leaves, reddish borders on leaves and shrivelled, tan lesions on the lower stem. Experience has shown that the combination of wrinkled, pliable roots without feeder roots is characteristic of fusarium. However, other symptoms are easily confused with other diseases such as rusty root (cylindrocarpon) or damage to feeder roots (pythium). Accurate diagnosis generally requires submission to a laboratory.

Factors Promoting Disease

Infection of ginseng by *Fusarium* is favoured by warm, wet soil conditions. *Fusarium* can occur throughout the growing season, but it may become more active as the soil warms. *Fusarium* will have a greater impact on plants which are stressed or wounded. *Fusarium* occurs in patches throughout gardens but, unlike rhizoctonia, these spots do not tend to spread in a circular fashion.

Disease Management Practices

Cultural

Fusarium can be spread through contaminated cereal straw or seeds. Check with suppliers to ensure the source of straw was not impacted by high levels of *Fusarium* and was treated with appropriate controls. Check ginseng seed after stratification for presence of *Fusarium* sporodochia. These can be seen under good light as white to pink, "pin cushion-like" bumps on the seed surface. These bumps could be indicative of *Fusarium* or *Cylindrocarpon* and for either pathogen, when the fungal structures are observed on the seed surface, the fungus will be inside the seed. Discard all contaminated seed.

Using Fungicides

There are no products registered for control of fusarium on ginseng.

Cylindrocarpon Diseases of Ginseng

Cylindrocarpon destructans

The Fungus and Symptoms

Cylindrocarpon is a soil fungus closely related to *Fusarium*. It is found worldwide in ginseng-growing areas. One of the most severe diseases of ginseng, it is frequently found associated with seed after stratification in buried seedboxes.

Seedlings attacked by cylindrocarpon may die before or after emergence. The fungus can attack the root and cause a dark rot that destroys the entire root (Plate 75, page 101). The fungus can also be associated with seedling roots (Plate 76, page 101). *Cylindrocarpon* has been recovered from roots that are stubby (Plate 77, page 101) or have a "rusty" netting on the surface (Plate 78, page 101). Occasionally, these plants may go on to harvest with no further decay, but roots will remain distorted.

Cylindrocarpon is more commonly associated with older roots. Spores of the fungus are stimulated by root exudate (substances that leach out of the root). When the spores are present in a garden, more plants will become diseased as the garden ages. Gardens that have a population of plants infected with this fungus in the second year will have at least double that infection level early in the third year. In older gardens, disease spreads rapidly towards the end of the season.

Above-ground symptoms of *Cylindrocarpon* infection are often undetectable even after the decay has progressed to make the root unmarketable (Plate 79, page 102). The disease is most frequently associated with red leaf perimeters. This can be confused with *Phytophthora*, where leaves can take on a reddish tinge, and with *Fusarium*, where leaf perimeters are

often reddish and yellow. Wilting plants are a sign of advanced decay (Plate 80, page 102).

The most common root symptom of infection by *Cylindrocarpon* is "disappearing root" rot. Roots with this symptom are reduced in the advanced stages to a blackened stub (Plate 75, page 101). Other symptoms include darkening of the outer areas of the root and a definite scaling of the root surface (Plate 81, page 102). The scaly area often covers an orange, spongy layer just below the surface (Plate 82, page 102). Spores are most frequently produced later in the season and are quite distinctive under the microscope. When these symptoms are present in a garden, it usually indicates that the pathogen is very aggressive, and spread can be amazingly rapid.

The symptoms of *Cylindrocarpon* infection can be confused with symptoms of rusty root/rust spot and *Rhizoctonia* infection. Microscopic analysis or growing the fungus on a selective medium is the only way to know what has caused this root decay. Research has indicated that there are a number of strains of *Cylindrocarpon* in the soil. These strains vary in their aggressiveness and in the severity of disease. Weakly pathogenic strains can cause rusty scabs and patches (see *Rusty-Root and Rust Spot of Ginseng*, page 61) but may not progress to a deeper decay (Plate 83, page 102).

Occasionally, roots infected with *Cylindrocarpon* will also become infected with *Rhizopus*. *Rhizopus* is not normally considered a pathogen on ginseng. It can cause root darkening during drying under some conditions. See *Rhizopus Rot*, on page 42. In the field, *Rhizopus* can infect ginseng roots only if the roots are damaged, usually by infection with *Cylindrocarpon* and if environmental conditions are wet. The decay that results from the combined action of *Rhizopus* and *Cylindrocarpon* involves the entire root and leaves a shrunken mass with a white, sticky interior (Plate 84, page 102).

Factors Promoting Disease

In spite of its seriousness and worldwide efforts to control this disease, little is known about the factors that promote infection. *Cylindrocarpon* can be present in a garden, and few plants may succumb. In other gardens, plant loss may be as high as 90%. This can be explained in part by noting the varying levels of aggressiveness of the different strains.

There are, nevertheless, some factors that are becoming evident. *Cylindrocarpon* is more prevalent in areas of former fence lines. It is more common near forested areas and in areas where brush has recently been

burned. Gardens where there is excessive nitrogen use have more severe disease outbreaks.

Seeds infected with *Cylindrocarpon* may decay and be culled out as "floaters." However, many infected seeds do not decay, and the only evidence of *Cylindrocarpon* infection is the pink or white "sporodochia" on the seed surface (Plate 32, page 94). Surface sterilization will eliminate the threat from this fungus on the seed surface but will not eliminate the fungus from the interior of the seed. Visual culling of seeds with sporodochia is the only way to avoid planting these infected seeds in the garden. When gardens are seeded at the rate of 113 kg/ha (100 lb/acre), even a 10% infection level in the seed will introduce about 210,000 sources of infection (infected seeds) in a single hectare. There is evidence to suggest that *Cylindrocarpon* may be seed-borne (infected during seed development in the field). Avoid picking and using seed from gardens known to be infected.

Disease Management Practices

Cultural

Be diligent in culling seed with sporodochia. Take care not to use seed from gardens known to be infected with *Cylindrocarpon*.

Garden sanitation is essential. Wash equipment between gardens. Have workers wear disposable "booties." Take care not to move from diseased gardens to disease-free gardens.

Site selection and the use of disease-free seed are the most important factors in control at this time. Stay away from areas recently forested and from former fence rows.

Site selection is also important for the seedbox. *Cylindrocarpon* can be picked up on the seed during below-ground stratification, and infected seed can be transported to new gardens. Controlled stratification above ground may help to prevent seedbox contamination.

Using Fungicides

There are no chemicals registered for use against *Cylindrocarpon*.

Table 5-1. Quick Disease Reference for Ginseng

Disease Organism	When to Look	Where to Look	What to Look for
<i>Rhizoctonia</i>	<ul style="list-style-type: none"> throughout the season especially in seedling and 2-year gardens 	<ul style="list-style-type: none"> on the stem within or below the mulch on the crown area of the roots on buds 	<ul style="list-style-type: none"> dry tan lesion on the stem rusty lesions on the crown and/or bud rusty lesions on the shoulder of roots absence of fibre roots
<i>Botrytis</i>	<ul style="list-style-type: none"> throughout the season after mechanical damage during humid weather 	<ul style="list-style-type: none"> on the straw on leaves within the canopy at the base of stems on flowers and berries 	<ul style="list-style-type: none"> black sclerotia on the straw soft lesions on leaves at the edges or tip leaves appear to "melt" and stick to adjacent leaves soft brown lesions with grey, fuzzy conidia dark brown or purplish shrivelled berries
<i>Alternaria</i>	<ul style="list-style-type: none"> throughout the season 	<ul style="list-style-type: none"> on the stem above the mulch on the leaves on the berries on the petioles supporting the leaves and flowers 	<ul style="list-style-type: none"> brittle tan lesion on the stem, "sooty" spores leaf lesions with "halo" tan leaf lesions with concentric circles of light and dark water-soaked or black lesions in hot, humid weather dry, brown berries dry, brown flower and/or seed stems
<i>Phytophthora</i>	<ul style="list-style-type: none"> in wet areas after prolonged wet weather 	<ul style="list-style-type: none"> along the edges of the beds beside standing water where water splashes into the middle of the beds 	<p>Root Rot</p> <ul style="list-style-type: none"> soft, dark, collapsed leaves one leaf wilts first leaves may have "purplish" tinge roots pinkish brown with "cheesy" interior and a sour smell <p>Leaf Blight</p> <ul style="list-style-type: none"> dark-green, soft lesions beginning at the tip cottony fungal growth
<i>Fusarium</i>	<ul style="list-style-type: none"> throughout the season 	<ul style="list-style-type: none"> on the stem within the mulch on the main root or fibres 	<ul style="list-style-type: none"> shrivelled tan lesion on the lower stem leaves may have reddish borders plants may wilt and droop just below the junction of the leaves roots that appear pliable and wrinkled rusty lesions on the root
<i>Cylindrocarpon</i>	<ul style="list-style-type: none"> throughout the season especially in 3- and 4-year gardens 	<ul style="list-style-type: none"> on the root 	<ul style="list-style-type: none"> dry, rusty lesions on the main root, crown or fibre roots absence of fibre roots dark, crusty lesions on the main root with an orange, crumbly subsurface layer or resembling those of <i>Fusarium</i>
<i>Pythium</i>	<ul style="list-style-type: none"> throughout the season particularly during time of high plant stress 	<ul style="list-style-type: none"> on the root 	<ul style="list-style-type: none"> soft, brown root tips root tips slightly swollen a proliferation of fibre roots decayed areas will be softer than <i>Phytophthora</i>

Rusty-Root and Rust Spot of Ginseng

Ginseng can develop symptoms on the exterior of the root that are often referred to as rusty-root, rust spot, rust or rusted root. The disease/disorder often consists of superficial, flaky, rust-coloured damage that can be scraped off with a fingernail leaving healthy tissue beneath. Sometimes symptoms can also be deeper into the root with a corky texture below the surface. The symptoms can be located anywhere on the root, but more often they are located closer to the crown. Rarely are there any visual symptoms of injury to the tops, and often the damage does not interfere with the normal growth of the plant. The main problem with these symptoms is the reduction in marketability of the roots.

It is important to know that rust symptoms on ginseng roots can be caused by a number of different diseases and disorders. In some cases, the symptoms develop as a response of the root to an infection or adverse environmental condition. For example, many plants have the ability to identify when a fungus has invaded the plant, and can kill off the infected tissue to prevent the fungus from destroying the whole plant. The roots may be sacrificing the outer layers of the root to prevent a fungus from infecting the whole root. In other cases, the rusty symptoms may just be dead and dried-up tissues of the root. Do not confuse rust symptoms on ginseng roots with true rust diseases on other crops such as wheat and corn. Rust on those crops is caused by completely different fungi and occurs entirely on above-ground plant parts; the rust symptoms are due to spore-producing structures of those fungi. Management techniques used for true rust diseases will have no effect on rust disorders of ginseng.

Once rust-like symptoms develop on ginseng roots, there is usually nothing that can be done to fix the problem. Management of the disorder requires an adjustment of production practices to avoid roots developing symptoms. One of the biggest challenges when dealing with the problem is identifying the cause. Multiple factors (both disease and abiotic) can cause similar symptoms. Proper diagnosis is essential before production practices can be modified to prevent problems in future gardens.

Rusty-Root Causes

Rust-coloured symptoms have been associated with several different fungi including *Cylindrocarpon*, *Fusarium* and *Rhizoctonia*. To keep these biotic causes of the symptoms separate from abiotic factors such as cold temperature damage, the term “rusty-root” will be used in this book to refer to the mostly superficial, rust-coloured symptoms caused by these fungi. However, it should be noted that symptoms of rusty-root appear very similar to the symptoms caused by abiotic factors such as cold temperature damage. It has been suggested

that minor damage due to the root-lesion nematode could cause rusty-root symptoms or could lead to fungal infection and eventual development of rusty-root symptoms. However, a link between nematode damage and root disease has not been conclusively proven.

Proper identification of the fungal causes can only be done by someone trained in pest diagnostics. In most cases it is impossible to determine the cause of rusty-root based on symptoms alone. Occasionally, the root can have a crumbly or soft texture below the surface that penetrates deeper into the root than the superficial symptoms associated with abiotic disorders (rust spot). However, deeper symptoms do not necessarily always appear. Proper diagnosis can even be challenging for trained diagnosticians because it is often difficult to determine if a fungus that is found in the root is the primary cause of the problem or if the fungus is secondary and came in after the root was already damaged. For information on the biotic causes of rusty-root see *Cylindrocarpon Diseases of Ginseng*, on page 58, *Rhizoctonia Diseases of Ginseng*, on page 50, *Fusarium Diseases of Ginseng*, on page 57, and *Nematodes*, on page 66.

Rust Spot Causes

To keep the abiotic causes of rusty-root separate from rusty-root caused by pathogens, it has been suggested that the term “rust spot” be used to refer to rusty-root symptoms caused by abiotic sources. That is the term that will be used in this book.

Rust spot consists of scaly, rust-coloured areas (Plate 85, page 103), usually on the taproot, often near a fibre or branch, that may or may not penetrate to the root interior. It is possible that these areas can be sloughed off without further root rot. In rust spot, there is no crumbly layer underneath the surface of rusty lesions as would occur in the presence of *cylindrocarpon*.

Research conducted by Agriculture and Agri-Food Canada, Summerland, British Columbia, indicates that rust spot can be caused by adverse environmental conditions. Low temperatures where roots are exposed to -6°C or lower can cause rust spotting. Fluctuating temperatures appear to be more damaging to the roots than prolonged low temperatures. In some cases, the resulting decay will be deep, in others it will remain superficial (Plate 86, page 103). Superficial rust spot only penetrates the periderm tissue. It can be scraped off with a fingernail but will not rub or flake off during drying (Plate 87, page 103). Even superficial rust spotting will devalue a root.

Other research has indicated that rust spotting is associated with high manure levels, excess nitrogen or the use of the ammonium forms of N, and the reduced form of iron that occurs in wet soils.

In the laboratory, rust spotting has been generated by exposing roots to ethylene. Similar symptoms can also be caused by boron toxicity (see *Boron Toxicity*, on page 73).

Diagnosing the Cause of Rusty-Root and Rust Spot of Ginseng

While it can be difficult to determine the exact cause of rusty symptoms on ginseng roots, there are some things a grower can do to narrow down the possibilities.

Location

Knowing where in the field the symptoms have developed and the distribution of the damage throughout the field can provide some clues to the potential causes. If the symptoms are evenly scattered throughout the field, but not every plant is affected, then it is possible that the problem is seed-borne. This could potentially signal a biotic cause of the problem because fungi (e.g., *Cylindrocarpon*, *Fusarium*, etc.) can infect the seed and would be scattered relatively evenly through the field during seeding. If the problem is seed-borne, then different seed-lots may develop differing amounts of damage.

If the symptoms are in larger patches in certain areas of the field, the problem could still be biotic but more likely caused by soil-borne pathogens. All three biotic rusty-root or similar symptom causes, *Fusarium*, *Cylindrocarpon* and *Rhizoctonia*, can be patchy in the field. If a biotic cause of rusty root is likely, it is necessary to have the roots examined by someone trained in pest diagnostics. This is necessary for two main reasons:

- Knowing the exact cause of rusty root symptoms can help in the selection of control strategies that have the most potential for succeeding.
- The diagnostician will gain a better understanding of the causes of rusty root that will allow for the development of control strategies in the future.

If the cause of the symptoms is low temperature injury, there may be more damage in low areas of the field where cool air would pool on cold nights. Symptoms caused by boron toxicity or excess use of manure or nitrogen would be more widespread in the field.

It is a good idea to keep track of where rusty root symptoms develop in a field and keep track of any differences in production practices that could account for those symptoms. Over time, patterns could develop that may help in the identification of the cause of the problem.

Field History

It is always a good idea to have a written history of the crops grown on a field and the production practices used in those crops. Matching location of the symptoms to differences in field history from one location to the next could also help narrow down the possible causes of rusty-root and rust spot.

Fungicide Resistance

What Is Resistance?

Fungicide resistance is the ability of a fungus to survive in the presence of normally lethal doses of a fungicide. If the fungus is a pathogen that causes plant disease, then fungicide resistance means that the application of that fungicide will not control the disease.

The importance of resistance management cannot be overstated. Very few new fungicides have been registered for use in Canada in recent years, consequently the existing products registered on ginseng must be used carefully.

How Does Resistance Develop?

Fungi, like populations of any other organism, are made up of a mixture of individuals with different traits. When this trait is resistance to a fungicide, it means that every time that a particular fungicide is applied, there will be more resistant individuals that survive compared to sensitive individuals. There are two ways that resistance can develop:

- It can exist naturally at varying levels in a population. When this is the case, the repeated use of the fungicide quickly "selects" for resistant individuals and they soon dominate the population.
- It can develop as a result of natural mutation. Because fungi generate so many spores, there is a chance that a mutation will occur during cell division that imparts resistance.

However resistance develops, when the population of resistant individuals is high enough, control (by that particular fungicide) will fail. There are some key differences between failure of a particular fungicide to control disease and overall control failure. **Control failure is not related solely to resistance**, and sometimes not at all. There may be other insurmountable problems that bring about unrelenting spread of disease.

What Kind of Product Could Develop Resistance?

Not all products are created equal. Fungicides are effective because they interfere with the natural processes a fungus needs to develop and live. Some fungicides interfere with a single process; some interfere with multiple processes. Generally speaking, each process is governed by a single gene in the fungus. Resistance is more likely to develop if only one genetic change is needed than if many simultaneous changes are required. Fungicides that have single sites (or very few sites) of action are considered a potential risk for the development of resistance. These are called "narrow spectrum" fungicides. Ridomil, Quadris and Rovral are three fungicides used in ginseng gardens that have a potential for resistance. Once resistance develops, it may take several years for the population of fungi to become susceptible again after the use of the fungicide is stopped. In some cases, susceptibility never returns. Doubling or even quadrupling the fungicide dose will not overcome this. Resistant fungi usually have the ability to tolerate ten-to-several thousand times the rate of a fungicide.

Ultimately this means that the use of narrow-spectrum fungicides must be carefully managed.

Using Fungicides Effectively in Ginseng

Eight factors are important in effective fungicide use.

Timing

Application must be made in time to protect the plant. Most fungicides used on ginseng do not cure disease. They protect the plant from attack and prevent or interfere with the initiation of the disease process. Protection must be in place before the pathogen has the opportunity to penetrate the plant where it is less likely to be affected by the fungicide.

Rate

Always use the label rate. Too much will hasten the development of resistant strains. Too little will not be effective. Label rates were designed and tested to give optimum performance. Do not assume that the rate used to control one fungus will control other fungi.

Coverage

Thorough coverage is essential for good control, including the upper-leaf surface, lower-leaf surface and stem. To be effective, a fungicide must be delivered to the target fungus. High water volumes may be required to situate the fungicide in the soil where soil-borne disease is a concern. Low water volumes may be required when a fungicide must be absorbed by the plant in order to be effective against the target fungus.

Rotation

Do not repeatedly use the same product, or products in the same chemical family, back to back in a control program. The mode of action of fungicides is usually based on their molecular structure. Members of a "chemical family" have similar structure and therefore similar mechanisms of action. This also means that if resistance develops to one member of a chemical family, other members of that family will also be ineffective.

Seeding Rates

Use all means of lessening the impact of pathogens in a garden. Avoid high plant density. Ginseng self-thins to about 80–100 plants/m². High initial seeding rates do not result in higher plant stands after 3 or 4 years. They do, however, put young gardens under stress, and the short distance between roots underground means that fungi have easier access to the next plant. Seeding rates of 89–112 kg/ha (80–100 lb/acre) are adequate for most gardens.

Water Management

Landscape gardens for effective surface water removal. Manage surface water with perimeter trenches and collection ponds. Pay careful attention to natural water flow and take measures to accommodate it. Trenches where water collects should have gravel, wood chips or straw to prevent splashing. Subsoiling the trenches helps drainage and soil compaction. See *Water Management*, on page 31.

Fertility Practices

Practices that promote lush canopy development also promote conditions favouring disease. Excessive canopy development makes stem coverage more difficult. Poor stem coverage is one of the leading factors in the development of *Alternaria* and *Botrytis* "hot spots" in a garden. See *Factors Promoting Disease*, on page 57, and *Disease Management Practices*, on page 55.

Air Circulation

Plant spacing and garden design should have air circulation in mind. Stagnant air pockets mean areas of prolonged high humidity. This promotes the development of disease, especially within the leaf canopy.

Table 5–2. Disinfecting Equipment

Sanitizing Compound	Mixing Rate With Water
hypochlorites (bleaches 5.256% active) ^{1, 2}	1 part bleach to 9 parts water
quaternary ammonium (10% active)	1 part ammonium in 300 parts water
37% formaldehyde (Formalin) ²	3 parts Formalin in 100 parts water

¹ Corrosive to metal. Residues on machinery may harm plants. Rinse well.

² Wear a suitable respirator. Ventilate following treatment. Fumes are toxic to plants and humans.

Sanitation

Sanitation is a key procedure in maintaining garden health and preventing the spread of disease. Wash equipment thoroughly before entering a healthy garden. Train workers to wear disposable booties when weeding, deflowering and picking berries. Sanitation is also important in the post-harvest handling of ginseng roots. See Table 5–2, *Disinfecting Equipment*, this page, for appropriate sanitizers. For a discussion of sanitation in coolers and kilns, see *Sanitation During Conditioning and Drying*, on page 42.

Disinfecting Equipment

Ginseng diseases can be spread via machinery. When moving from garden to garden, work in younger gardens first. After working in diseased gardens, wash all equipment with a high-pressure washer to remove soil and plant debris. Disinfectant applied to clean equipment will help prevent the spread of ginseng pathogens.

Diseases can also be spread on boots and clothing. When entering a garden, make sure that the soles of boots have been cleaned or change to a new pair of disposable plastic booties.

Pesticide Application Technology

There are many useful application technologies and pest control products available to growers, but their effectiveness depends on correct usage. Effective application begins with observing the integrated pest management (IPM) process: diagnose the problem, monitor the problem, control the problem and monitor the results. If spraying is warranted, the operator should understand the basics of application technology. This not only includes the equipment,

but the effects of changing spraying parameters (such as pressure or carrier volume), the impact of weather conditions (such as wind and relative humidity) and the product being applied (such as correct timing and safety requirements). The operator should also understand how to properly maintain, calibrate and orient the sprayer according to the nature of the target. Finally, monitoring the results requires the operator to respond to changes in the environment and target during application and to consider these factors when evaluating the outcome.

Pesticide Drift

Pesticide drift occurs in two forms: Particle drift is the physical movement of spray particles through the air from the target site to any non-target site at the time of application. Vapour drift can occur during or after the time of application and is more a product of the environmental conditions than the equipment used.

The potential impact of pesticide drift includes a reduction in product efficacy, the contamination of populated or sensitive environmental areas, the development of pesticide resistance in key pests and the financial loss associated with wasted chemical inputs. Pesticide drift concerns all operators. Aim to minimize or eliminate all forms of drift.

Disease Control

Ginseng roots increase in size each year from July through September. A 3-year-old garden can increase in yield by 560 kg/ha (500 lb/acre) during such a growth period. Foliar diseases can cause serious economic loss during this root growth period by reducing overall yields. Losses can also occur as a result of stem canker and reduction in photosynthetic surface due to lesions and defoliation caused by the fungi *Alternaria panax* and *Botrytis cinerea*. The initial focus of these diseases is usually the stem. If fungi are left unchecked, leaf disease and head blight will follow. Defoliation can occur within 7 days of infection in an untreated garden. Once foliar disease becomes established in a garden, growers are forced into a 7–10-day treatment schedule.

Control of diseases on the stem and in the leaf canopy first depends on the selection of appropriate fungicides and then on how effectively the product is deposited on the target (e.g., on the entire plant or on a specific part of the plant). To control fungi that attack the stems, seed heads and leaves, pest control products must thoroughly cover all these parts, including the underside of the leaves.

Fungicides

Most fungicides used in a ginseng disease control program are protectants. These products form a protective barrier on the plant that kills or inactivates certain fungi. Protectants are effective as long as they remain on plant surfaces. Repeated rainfall will reduce the amount of fungicide present.

Other fungicides, such as Aliette, are systemic and must be absorbed by the plant. Generally most active after uptake, Aliette causes the plant to mobilize its own internal defence mechanisms but is not directly active against pathogens. It must be absorbed by the plant to be effective and should remain on the leaf surface for 1 hr.

Always follow the label instructions when applying fungicides. To check label information, visit the PMRA (Pest Management Regulatory Agency) website at www.pmra-arla.gc.ca, click on Label Search and type the name of the chemical in the query box. While the Electronic Label Search Engine (ELSE) is a good source of quick information, the most recent changes to a label may not yet be posted. Always check the actual label before using any pest control product.

Hydraulic Nozzles

Nozzle Materials and Maintenance

Depending on the product being applied, plastic nozzles wear at least as well and usually better than steel. Ceramic is the most wear-resistant material available. The initial cost for wear-resistant nozzles might be higher, but the long life will offset the cost. Do not mix nozzle materials on a boom, and with the exception of end nozzles, do not mix nozzle types. They wear at different rates and may produce uneven spray distribution.

Always use care when cleaning. Carry a few extra nozzles for quick replacement if they get plugged. Nozzle tips are prone to deformation if cleaned with hard objects such as fine wire or even a toothpick. Use a soft bristled brush (like a toothbrush). A spray nozzle worn by even 5% may not give uniform or consistent coverage, resulting in under- or over-application. Recommended practice is to replace all nozzles at the same time when worn nozzles are detected.

Spray Quality

Hydraulic nozzles can be classified by their geometric spray patterns, flow rates and the range of droplet sizes they produce, collectively referred to as "spray quality." Pesticide labels increasingly specify droplet size as well as flow rate and should be carefully considered when selecting nozzles. Table 5-3, *The Impact of Droplet Size*, this page, compares the relative merits of three droplet sizes but is not definitive.

Table 5-3. The Impact of Droplet Size

Droplet Size	Drops per Area	Retention	Canopy Penetration	Drift Potential
fine	high	high	low	high
medium	moderate	moderate	moderate	moderate
coarse	low	low	high	low

Nozzle Orientation

Position nozzles according to manufacturer specifications to optimize coverage. Generally, lower boom heights will reduce drift while higher boom heights increase spray overlap for proper spray uniformity. If using flat fan nozzles, larger angles (such as 110°) will allow lower boom height and fewer nozzles without compromising uniformity. Many ginseng boom sprayers employ hollow cone disc core nozzles on 30-cm centres. Nozzles on boom ends are directed at post rows, and drop arms are positioned behind tractor wheels (and/or between beds) with nozzle tips directed back up into row canopies. This arrangement provides adequate coverage of the upper and lower leaf surfaces and of the stem and seed head, where disease most frequently begins. Vertical targets (such as stems and seed heads) receive better coverage using dual-fan nozzles, where one fan is oriented in the direction of travel and the other is oriented away. This has been demonstrated in several crops but has not yet been confirmed with ginseng. Operators are encouraged to recalibrate their sprayers as the season progresses, not only to confirm good working order, but to reorient nozzles and boom height to match canopy changes as they grow and fill.

Sprayer Parameters

Pressure

Hydraulic nozzles produce finer droplets at higher pressures and coarser droplets at lower pressures. Many operators modify operating pressure to affect application rates during spraying, but this is not a recommended practice. It takes a four-fold increase in pressure to double flow rate, and even minor increases in pressure decrease droplet size, widen spray swathes, increase drift potential and reduce the life of the nozzle. Conversely, reducing pressure below rated minimum will compromise the spray pattern. When selecting a nozzle, plan to consistently operate it in the middle of its recommended operating range to allow for minor adjustments in speed and pressure during spraying. If a different rate is required, use nozzle flips to quickly switch to a different nozzle.

Carrier Volume

A leaf can retain only a limited volume of spray, so once wetted, the surplus runs off to the lower

leaves and on to the soil. Once run-off has begun, the amount of product deposited will not increase beyond the concentration applied, no matter how much volume is used. If properly calibrated, the same amount of product should be deposited on all portions of the target without incurring run-off. In 2000, a comparison of Ontario ginseng sprayer technology demonstrated improved coverage and penetration using a boom sprayer applying 1,685 L/ha (180 U.S. gal/acre) using fine droplets at a forward speed of no more than 5.0 km/hr. For more information on ginseng sprayers, see the OMAFRA website at www.ontario.ca/crops.

Timing and Travel Speed

Timing relates to the pest growth stage, pest pressure, weather conditions and work rate, so it is sometimes tempting to rush an application to fit a limited window of time. However, higher speeds increase potential for drift and can distort the spray pattern. Slower speeds yield better results by giving spray more time to penetrate the canopy.

Canopy Penetration and Coverage

Obtaining a balance between canopy penetration and foliar coverage does not always require a compromise. While it is true that larger droplets improve penetration, while finer droplets improve coverage, higher carrier volumes and slower forward speeds have a greater impact on penetration than manipulating droplet size. Many studies have demonstrated that air-assist technology increases canopy penetration by displacing leaves and greatly reducing the incidence of drift. If air assist is employed, select a rate that rustles leaves enough to open holes in the canopy, but not so high as to damage seed heads. The importance of coverage in the control of foliar diseases cannot be overstated. It is the first factor to consider when protection fails. Frequent sprayer calibration will help ensure that your sprayer performs at its optimum level. If coverage is adequate, and the choice of fungicide appropriate, but disease remains uncontrolled, consider the possibility that resistance has developed.

Nematodes

Nematodes are tiny, worm-like animals that live in soil, water and plants. Plant parasitic nematodes invade roots and feed on plant tissue. They inject a variety of enzymes into plants that decompose plant cells and, for some nematode species, induce production of enlarged structures (knots or galls). Nematodes damage plants by interfering with the transport of nutrients, producing toxins that kill host tissue and inducing

abnormal plant growth. Furthermore, wounds caused by nematode feeding can facilitate infection by other soil-borne pathogens. In Ontario, root-lesion and root-knot nematodes are abundant in ginseng-producing areas. Both can affect yield and quality in ginseng.

The root-lesion nematode is common in ginseng-growing regions of Ontario and has a wide host range. This nematode moves in and out of the root along its length, leaving linear, scratch-like lesions and rupturing the epidermis of cells as it travels. In ginseng, these lesions may appear orange due to the production of chemicals by the plant in response to injury. Nematode damage to tap roots and subsequent production of secondary roots can lead to a spider-like appearance of harvested roots. It has been suggested that some cases of rusty root may be attributable to nematodes (see *Rusty-Root and Rust Spot of Ginseng*, on page 61). It is important to remember that the signs of nematode damage are very similar to those caused by a variety of other soil-borne pathogens as well as to rust spot, which is due to abiotic factors. Submit roots with these symptoms to a lab for diagnosis to determine the cause. For nematode diagnosis, follow the procedures outlined in Appendix B, *Diagnostic Service*, on page 80.

Scarring on small, developing roots from nematode feeding may lead to rusty root and the formation of prongs. Wounds on the roots from nematode feeding may encourage invasion by *Pythium*, *Fusarium* and *Cylindrocarpon*. There is some evidence that there is a synergistic effect between root-lesion nematodes and *Cylindrocarpon*, and that the resulting root rot is greater than either pathogen by itself. Ginseng roots in the seedling year are especially vulnerable to damage from root-lesion nematodes.

The root-knot nematode has also been found in association with ginseng roots. This nematode causes galls to form on the roots, making them unmarketable (Plate 88, page 103).

Above-ground symptoms of nematodes include variable stands (dense plant populations that thin out completely in some areas), senescence and stunted plants. These symptoms can be mistaken for nutritional deficiencies.

Cultural and Chemical Control

No thresholds have been established. Preplant fumigation is effective in controlling nematodes, however it is critical that this be done properly. See *Fumigation*, on page 34, for more information. It has been suggested that rye nurse crops, with their extensive fibrous root system, may attract nematodes

back to fumigated soil and allow them to persist. These nematodes could then move onto ginseng crops after burn-down of the rye.

Insects

See Table 6–3, *Insect Control Recommendations for Ginseng in Ontario*, on page 76, for insect control recommendations.

Cutworms

***Peridroma saucia* (Hbn.), *Agrotis ipsilon* (Hufn.), *Euxoa messoria* (Harr.)**

Cutworms are the larvae or young of night-flying moths in the family Noctuidae. There are about 20,000 species worldwide. The larvae of most of these species feed on a variety of plants and are serious pests. Several species will attack ginseng in Ontario, with the most common being the variegated cutworm *Peridroma saucia* (Hbn.), the black cutworm *Agrotis ipsilon* (Hufn.) and the dark-sided cutworm *Euxoa messoria* (Harr.). The particular species found in a garden depends on the geographic location.

Cutworms overwinter as eggs, larvae, pupae or adult moths, depending on species. In areas where winters are severe, the moths of some species fly in from the south each year. The cutworm moths that affect ginseng are attracted to low, wet, grassy areas. Germinating grain kernels found in the straw used to mulch a ginseng garden are very attractive to cutworm moths. The time of egg-laying depends on species and geographic location. During the growing season, cutworm larvae spend most of their days several centimetres below the soil surface. They emerge in the evening and begin to feed on the crop. This key feature of their behaviour is useful in determining the method of control.

Cutworm larvae are soft and fat, and approximately 3.8–5 cm in length. The body usually appears greasy and varies in colour from grey to brown with darker markings. The most distinguishing feature of cutworm larvae is their habit of curling into a “C” when they are disturbed (Plate 89, page 103).

Cutworms are most damaging to small plants. Cutworm damage to seedlings can kill the developing plant. If cutworms are present in seedling gardens, the tops of emerging seedlings can be completely chewed off. After such damage, roots are easily invaded by weak pathogens such as *Pythium*. Sometimes the first evidence of cutworms will be the severed leaves laying upside-down on the straw (Plate 90, page 103). Some

species of cutworms will eat holes in the leaves; some will chew off stems.

Cultural Control Practices

Avoiding or removing stands of grasses or grains will deter egg-laying.

Using Pest Control Products

The most effective control for cutworm larvae is treatment with an insecticide.

Most of the damage from cutworms in ginseng will be on the outer edges of a garden. Often a border treatment is sufficient to get good control. It is important to wait until damage is evident and the presence of cutworms is confirmed before treating. Cutworm damage can be confused with feeding damage of white grubs (European chafer) and sometimes with slug damage.

See Table 6–3, *Insect Control Recommendations for Ginseng in Ontario*, on page 76, for recommended control products for cutworms in ginseng in Ontario.

European Chafer

***Rhizotrogus majalis* (Raz.)**

The larvae of the European chafer can be a pest in seedling ginseng gardens (Plate 91, page 104). These larvae are often referred to as “white grubs.” The term “white grubs” can also refer to the larvae of other species of chafer, including the June beetle, however, to date, only the European chafer has been found in ginseng. European chafers are a serious pest of turf in Ontario. In recent years, they have expanded their host range to include cereal crops, soybeans, potatoes and other horticultural and field crops. European chafer grubs are only observed sporadically in ginseng, but when they do occur the damage can be quite extensive.

In most crops, European chafer beetles are active from late June to August, feeding and laying eggs on a variety of crops. Eggs hatch in the fall, and the grubs overwinter deep in the soil as early instar larvae. Most feeding occurs the following spring, continuing until the larvae pupate in late spring. The life cycle of European chafer appears to be somewhat later in ginseng compared to other crops, as egg-laying has been observed to occur as late as the end of September in gardens. The adults are attracted to trees where they congregate and mate. Posts set into the beds of new gardens are also points of congregation. The females seek out mounds or grassy areas to lay eggs. Ginseng beds, especially after the volunteer cereals or nurse crops have germinated, are attractive to females. Egg-laying has only been observed in new ginseng gardens, with most of the

damage occurring the following spring, when ginseng seedlings emerge.

White grubs have six legs with a C-shaped white body and darker head. The tail end of the grub often appears dark due to soil ingested while feeding. Grubs feed on young roots in seedling gardens. As they feed, the young plant is slowly drawn into the straw (Plate 92, page 104). One grub is capable of completely devouring 10 or more seedling roots. The damage becomes more obvious in 2-year-old gardens, appearing as circular empty spaces in the beds (Plate 93, page 104), however the grubs themselves are usually not found in 2-year gardens. The feeding habit of grubs is easily distinguished from that of cutworms. Cutworms will “cut” the young stem, severing it completely, and the leaves are then left to rest, usually upside down, on the straw surface (Plate 90, page 103).

Cultural Control Practices

In years where European chafer adults are particularly active in turf and other crops, delaying bed formation until fall, after adults have flown, may reduce the problem.

Using Pest Control Products

See Table 6–3, *Insect Control Recommendations for Ginseng in Ontario*, on page 76, for recommendations to control chafer grubs in ginseng.

Four-Lined Plant Bug

***Poecilocapsus lineatus* (Fabricus)**

The four-lined plant bug will feed on ginseng of all ages but causes economic damage only on seedlings. It feeds on a wide range of cultivated herbaceous plants and woody ornamentals. The insect is a member of the true bug family and is a relative of the tarnished plant bug or lygus bug.

In the Northeastern U.S. and Canada, it lays eggs in the early summer, usually in slits in the canes of woody plants. The eggs do not hatch until the following spring. The nymphs appear, beginning in late May, depending on the temperature. Nymphs tend to stay in place on the plants where eggs were laid. Adults are very mobile. They can fly to new hosts to feed. Usually they remain in ginseng gardens a short time, but their feeding can cause serious damage to seedlings. Four-lined plant bug adults are most active in ginseng in late June and throughout July. Peak activity times depend on temperature.

The forewings of the adult range in colour from bright green to yellow with four distinct black stripes that extend the length of the wings, hence its common name. Adults are about 7 mm in length (Plate 94,

page 104). The young nymphs have wing pads instead of wings and brightly coloured markings ranging from red to yellow.

Both adults and nymphs have sharp mouthparts that pierce the ginseng leaf and suck out the leaf contents in a localized area. During the feeding process, all of the chlorophyll is removed and a “window” of upper and lower epidermis remains. During feeding, the insect injects a toxic salivary secretion into the leaf.

The spots that result from this type of feeding vary, depending on the host. In ginseng, fresh feeding areas are dark coloured but quickly become white or tan and papery. Spots are about 1–2 mm in diameter. If feeding is intense, the spots will coalesce (grow together). Because chlorophyll is removed during the process of feeding, smaller leaves may be unable to make enough starches and sugars to feed the root (Plate 95, page 104).

Feeding damage to older leaves has less impact. Even considerable feeding will leave most of the leaf surface with the chlorophyll intact. Large leaves would need over 50% damage to affect root growth (Plate 96, page 104).

Cultural Control Practices

It may be possible in some cases to lure this insect onto a trap crop, thus keeping it out of ginseng gardens. The four-lined plant bug prefers to feed on members of the mint family. Research has shown that this preference is a strong enough attraction to keep the insects out of a ginseng garden. Experiments in Ontario have found that planting a single mint plant at the end of a bay of field-cultivated seedling ginseng will keep the insect out of the ginseng under normal population pressures. It is not known if this method would be effective under high insect populations. The mint can be invasive but can be easily controlled by planting it into a tile or other barrier that prevents the roots from spreading. The mint can be killed back after the seedling year, because damage to older plants from the four-lined plant bug is usually minimal.

The population size of the four-lined plant bug varies from year to year. In addition to normal insect population cycles, insect numbers are affected by weather. Populations are higher in hotter seasons.

Using Pest Control Products

If applied as soon as feeding damage is noticed, insecticides may control the four-lined plant bug, but since the insect is so mobile, it could leave the garden before treatment is effective. See the insecticide recommendations in Table 6–3, *Insect Control Recommendations for Ginseng in Ontario*, on page 76.

Pit Scale

Asterolecanium arabidis (Signoret)

Ginseng can be affected by the pit-making *Pittosporium* scale. This insect can be found in the Eastern, North Central and Pacific coast states and in Eastern Canada. It attacks many woody and herbaceous plants. Its favourite hosts are mock orange, privet and green ash. It is also found on members of the Araliaceae family, which includes ginseng.

Adult scales are oval in shape and are about 3–4 mm in length. The colour of the insect's shell ranges from white to brown and the dorsal (back) surface is strongly convex (Plate 97, page 105).

Depressions or pits are commonly formed beneath the feeding insect. Once attached to the plant, the insect remains stationary.

The ginseng pit scale attaches to the stem and leaf petioles of the ginseng plant. A toxic substance in the insect's saliva is injected into the plant during feeding, which affects the growth of the stem and petioles. Stems and petioles can become severely twisted as a result of feeding by the pit scale (Plate 98, page 105). Plants affected in this manner will remain well below the leaf canopy and will have reduced ability to feed the roots. If the scale attaches to the flower stalk, the stalk will twist downward, and seed production will be limited.

Damage from the pit scale is seen later in the season. The pit scale is an occasional pest that may be found in gardens adjacent to wooded areas.

Cultural Control Practices

Culling affected plants should prevent the spread of this insect.

Using Pest Control Products

There are no pest control products registered for use against pit scale in ginseng.

Leaf Roller

Archips purpurana (Clem.), *Argyrotaenia velutinana* (Wlk.) (red-banded leaf roller)

Leaf rollers may attack ginseng from emergence to August. The most common species, *Archips*, is a general forest feeder and can be found on hosts such as blueberries, strawberries, violets, willow, goldenrod and sassafras, as well as ginseng. It seldom causes economic damage in ginseng.

Adult *Archips* is a small moth with a wingspan of less than 2.5 cm. It lays its eggs on ginseng, and the hatching larva "folds" a leaf around itself (Plate 99, page 105). The larva will grow to about 2.5 cm in

length (Plate 100, page 105). It leaves its leaf shelter daily to forage for food (in this case, ginseng leaves) and returns at dusk.

The leaf roller is most prevalent after late June and is more commonly found in older gardens. The most obvious symptom is the drooping, rolled leaves which the caterpillars use as a shelter between feedings. The caterpillar chews the leaf petiole on one side until the petiole bends but does not break. This interrupts the flow of sap to the leaf, which becomes slightly wilted but does not die.

Leaf rollers are occasional pests of ginseng and are more likely to be found near wooded areas. Their effect on yield has not been measured.

Cultural Control Practices

Removing rolled leaves after the insect has returned may prevent spread.

Using Pest Control Products

Apply pest control products while the insect is foraging for food. Once the insect has returned to its "nest," it is in a protected environment. See the control recommendations in Table 6–3, *Insect Control Recommendations for Ginseng in Ontario*, on page 76.

Mealy Bugs

Acanthococcus dubius (Cockerell)

A. dubius has occasionally been found in ginseng gardens. It is common in the Eastern U.S. as far north as Maryland. The species has no particular plant preference and has been reported on over 40 different hosts, including a number of trees, bushes, flowers and weeds. It can overwinter in Ontario in greenhouses and can arrive in ginseng gardens as an unwelcome "visitor" on shoes and clothing. Growers who grant tours of their gardens should be aware that their guests might bring pests with them.

Mealy bugs are soft-bodied insects that are usually covered with a waxy secretion. *Acanthococcus*, however, may be bare or only lightly covered with wax (Plate 101, page 105).

The egg cases of *A. dubius* are found primarily on the underside of the leaves. They are small, oval-shaped sacs about 1–3 mm in length and covered with a white, waxy secretion (Plate 102, page 105). Each egg case can contain many small, salmon-coloured eggs.

On ginseng, *A. dubius* usually feeds on the main veins of the leaves. Mealy bugs are sucking insects and obtain their nutrients by inserting long mouth parts into the plant and sucking out the plant juices.

A. dubius secretes a toxin into the leaf as it feeds. This toxin results in distortion of the leaf, especially along the main veins (Plate 103, page 106). Note the difference in the type of damage compared to the pit scale (Plate 98, page 105). The scale usually feeds on the stem and petioles.

Cultural Control Practices

It may be possible to prevent spread by removing affected leaves from the garden. Mealy bugs can travel on clothing and equipment. *A. dubius* may be present in some greenhouse crops in Ontario. Take care not to go from a greenhouse to the ginseng garden if the greenhouse is infested with mealy bugs.

Using Pest Control Products

There are no pest control products registered for use against mealy bugs on ginseng.

Stem Borers

There are several stem-boring insects that can attack ginseng. Some of these insects may be locally common in areas where there are numerous preferred host plants. Their presence on ginseng is often a coincidence, but some of them seem to have developed a preference for ginseng.

One insect that can be found boring inside ginseng stems is the European corn borer (ECB), *Ostrinia nubilalis* (Hubner) (Plate 104, page 106). The adult is a small moth. Although corn is the preferred host of the ECB, its host range is expanding to include a number of other plant species. As the larvae of these insects eat away at the interior of the stem, the plant wilts, and the top dies. If ECB is present in a ginseng stem, there will be a small circular hole in the stem.

Cultural Control Practices

The only way to control stem-boring insects in ginseng is to entirely remove the refuse of the crop after it dies back in the fall. Once removed, burn or bury the leaf and stem refuse.

Using Pest Control Products

There are no pest control products currently registered for use against stem-boring larvae in ginseng.

Aphids

Aphids are small, soft-bodied, pear-shaped insects with straw-like mouthparts that pierce plant tissue and suck the sap from a wide variety of crops. They can be identified by the presence of two "tail-pipes," called cornicles, near the end of their abdomen. Aphids reproduce very rapidly, and are usually found in groups, or colonies, on the underside of leaves, along plant stems

or on petioles. There are winged and wingless forms. Aphids are important pests of a wide variety of crops. Aphids damage plants in a number of ways. Feeding by large populations can distort plant parts and cause water stress and wilting. Aphids also secrete a sticky substance known as honeydew, which can promote development of fungi ("sooty mold"). On some crops, aphids can act as vectors of several viral diseases.

In ginseng, aphids can be attracted to the tender tissue of elongating stems holding flower heads. Ginseng has not traditionally been a preferred host for aphids, however they are observed sporadically in gardens and in some years, populations have built to sufficiently high levels to cause damage (Plate 105, page 106). Aphids typically cause shallow feeding scars and blemishes on flower stems. Where damage has been observed, it has been due to disruption of transport of nutrients and moisture from the stem to the seed head, causing seeds to shrivel.

Cultural Controls

Aphids have numerous natural enemies that can be quite effective in reducing populations. These include a number of predators (larvae of several flies and lacewings, lady beetle larvae and adults, earwigs and others) and various species of parasitic wasps, which lay their eggs inside the aphid. The developing wasp larvae feed on the aphid from the inside, ultimately killing it. Aphids are also susceptible to fungal disease. The presence of dry aphid carcasses, swollen, darkened aphids (due to the presence of a parasitic wasp) or aphid cadavers covered in fungal material indicates that these natural enemies are at work. These natural enemies can be affected by chemicals used to control other pests, so selection of pesticides with minimal impacts on these beneficial organisms can help to preserve their populations. For example, some pyrethroids applied for cutworm control can be harmful to beneficial insects, and certain fungicides applied for disease control can impact insect pathogenic fungi.

On some horticultural crops, it has been shown that managing nitrogen levels to prevent the excessive growth of tender tissue (preferred by aphids) can help reduce aphid populations. However, this has not been studied in ginseng.

Using Pest Control Products

There are no pest control products registered for use against aphids in ginseng.

Planthoppers

Planthoppers can be occasional pests in ginseng gardens. The adults are usually brightly coloured, but the nymphs are often coated with white filamentous wax.

Planthopper nymphs on ginseng produce a white sticky coating on stems and seed heads (Plate 106, page 106). This can make picking the berries unpleasant. Planthoppers are more of a nuisance than a serious pest. It has been noted, however, that on seed heads where planthoppers are present, there are berries with boreholes where the seed has been eaten away as shown on the stem on the bottom in Plate 106, page 106.

Other Pests

Slugs

Slugs are soft-bodied, legless molluscs that can feed on above- or below-ground plant parts. Insecticides will not control slugs,

In seedling gardens, slugs can damage the stems and the leaves. Young slugs will chew holes in the side of stems (as opposed to cutworms, which chew right through the stem) (Plate 107, page 106). They will also chew small ragged holes in the leaves (Plate 108, page 106). Feeding damage from very small slugs has the appearance of many buckshot holes in the leaves. It is sometimes the first indication that slug populations are increasing.

In older gardens, slug damage occurs most often on the leaves. There may or may not be a slime trail as the slug moves across the plant surface. The larger the slug, the larger the hole in the leaf. During berry development, slugs can chew holes in ripening berries (Plate 109, page 107) and into roots (Plate 110, page 107). This type of root damage is most common in the upper portion of the taproot.

Slugs are attracted to cool, wet areas and are most active at night. In ginseng, the straw mulch provides an ideal climate. Slugs are more likely to occur where ginseng follows sod, where there is a large amount of crop refuse and in heavy, poorly drained soils. Slugs can move into a ginseng garden from surrounding vegetation.

Monitor slug activity by cutting oranges or grapefruit in half and placing them, cut side down, at several spots in the ginseng garden. Inspect the fruit in the evening for the presence of slugs. This will show you if slugs are present but won't indicate the potential for damage. Slugs are also attracted to beer. Small, shallow tin plates, or tin cans, sunk into the soil to the rim and filled with beer can be good indicators of slug activity.

Cultural Control Practices

Certain cultivation practices can minimize slug damage. Work organic matter well into the soil and

compost it prior to seeding. In established gardens, maintain good drainage by grading the surrounding area for efficient surface water removal and by subsoiling the trenches each fall.

Barriers of hydrated lime, ashes, coarse sand or diatomaceous earth will act as deterrents to slugs invading the garden from the surrounding areas.

Using Pest Control Products

Slugs can be controlled with the application of the natural compound, ferric phosphate. Available product can be broadcast in the ginseng garden. It is relatively resistant to wet conditions. See Table 6-5, *Slug Control Recommendations for Ginseng in Ontario*, on page 77, for details about application rates and frequency.

Millipedes

Millipedes are generally considered beneficial in agriculture, because they feed on decaying plant material and help build up organic matter in soil. However, certain conditions can lead to a population explosion of millipedes. Under high population pressure, millipedes will attack a variety of root crops, including ginseng.

Millipedes have elongated, hard, cylindrical bodies that range in length from 1–10 cm at maturity (Plate 111, page 107). They range in colour from white to grey-black and tend to coil up when disturbed. They are not insects but are related to centipedes. They have numerous, uniform body segments and are distinguished by their many legs, with each body segment bearing two pairs of legs. Millipedes are often mistaken for wireworms and centipedes, however, wireworms have only three pairs of legs. Centipedes have only one pair of legs per body segment, and these are typically longer than millipede legs and tend to stick out further from their bodies.

In ginseng, millipedes have been observed sporadically attacking emerging seedlings. They may also consume the seed pulp when the seed cracks just prior to germination. Seedlings that make it to the soil surface and begin to extend above the straw may be chewed off where they break through the soil. This may be mistaken for damage caused by cutworms, slugs or even mice, but unlike these pests, millipedes will attack any plant part emerging above the soil and not exclusively the stem. However, when these symptoms are observed it is important to look for the pest to verify what is causing the damage.

Cultural Control Practices

Millipedes thrive in damp, dark places and damage to ginseng seedlings has mostly been observed

when conditions are cool and moist, such as during prolonged cool, wet springs. Millipedes have been problematic in gardens located in particularly wet areas, or where straw has been applied so thickly that the soil is unable to dry. In these cases, increasing drying of the soil (e.g., by removing some straw) has helped reduce millipede populations. In other Ontario root crops, millipedes have caused damage during dry summers. It is not known whether this would also be the case for ginseng.

Using Pest Control Products

There are no pest control products registered for use against millipedes in ginseng.

Rodents

Mice may damage ginseng by chewing on stems and exposed roots. Stems chewed by mice show large elongated areas of chewing (Plate 112, page 107). The mice tunnel beneath the straw mulch and tend to establish runways along the length of the beds. Mice may invade ginseng gardens in the fall if surrounding vegetation is removed.

There are no rodenticides registered for use in ginseng gardens. However, there are several strategies that can be used to reduce rodent populations in the field. Rodenticides may be registered for use in non-crop fields. In the preplant year, as long as there is no crop grown for food or feed, rodent populations could be reduced by placing these rodenticides in bait stations in and around the field. Bait stations must be tamper-proof and inaccessible to children and pets. They must be removed before ginseng is planted into the garden. Bait stations containing these rodenticides can also be placed in the non-crop areas surrounding an existing ginseng garden to prevent rodents from moving into the field, particularly in late summer through fall when rodents tend to move into gardens.

To identify applicable products, visit the Pest Management Regulatory Agency (PMRA) website at www.pmra-arla.gc.ca, click on Label Search, and type in rodenticide in the query box. Read the labels carefully to ensure they can be used for these purposes. Follow all label directions and precautions carefully.

Encourage birds of prey to perch around ginseng fields by erecting tall perches at intervals throughout the field. This will be only useful during periods when the shade cloth is pulled in fall and spring. Manual traps can also be used in ginseng fields throughout the season.

Weeds

The first defence against weeds is in the preplant year(s). See the section *Weed Management*, on page 33, for a discussion of weed management in ginseng gardens.

Weeds can be introduced into ginseng gardens with the mulch material. In every bale of straw mulch applied to a ginseng bed, there are approximately 73–109 L (2–3 bu) of kernels. Using a straw mulch that will not produce winter-hardy seeds or seedlings will help prevent volunteer grains in the spring. Use clean straw from fields with low weed populations.

Weeds can also enter gardens on the wind. A rye strip set against the prevailing winds around the garden border will stop some weed seeds from blowing into the garden. The rye strip will also help prevent sandblasting. In some years and some locations, there can be an influx of cedar or maple seeds. When these trees germinate in a ginseng garden, it is very difficult to remove them by hand weeding without dislodging the ginseng roots. If your garden is in an area where tree seeds may blow into it, erecting a barrier of polypropylene cloth set against the prevailing winds may help reduce the numbers of seeds entering the garden.

Hand-pulling is the most effective method of weed control in existing gardens. Hoeing is not an option, due to the high plant density of the ginseng plants.

The most significant weeds in ginseng in Ontario are wild buckwheat (*Polygonum convolvulus*), pigweed (*Amaranthus retroflexus*), cleavers (*Galium aparine*) and common chickweed (*Stellaria media*). Other weeds include field bindweed (*Convolvulus arvensis*), lamb's-quarters (*Chenopodium album*), dandelion (*Taraxacum officinale*), shepherd's-purse (*Capsella bursa-pastoris*), grasses and volunteer cereals from the straw mulch. All of these weeds are annuals except field bindweed and dandelion, which are perennials. The occurrence of perennial sow thistle (*Sonchus arvensis* L.) in ginseng gardens in Ontario is increasing.

See Table 6–4, *Weed Control Recommendations for Ginseng in Ontario*, on page 76, for weed control recommendations in ginseng in Ontario.

Abiotic Disorders of Ginseng

Heat Stress

Under conditions of extreme heat and drought, ginseng leaves will develop dry, tan areas (Plate 113, page 107). These areas can easily be confused with

symptoms of fungal infection. Roots that are damaged by root pruning will be the first to show symptoms of heat stress in a garden. Whether the symptoms are caused by root disease, high temperature or drought, the leaves will have the same appearance. This disorder is also called “papery leaf spot,” which aptly describes the condition. Once symptoms occur, there is little that can be done to revive the damaged tissue. Papery leaf spot can be prevented to some degree by allowing hot, humid air to escape from gardens through a series of vents where the shade material is slightly raised at intervals. Irrigation may also prevent symptoms. Any irrigation in ginseng must be balanced against the risk of phytophthora root rot.

Papery leaf spot will sometimes occur next to emitters during periods of trickle irrigation. It is believed that the abundant water makes the plants more succulent and hence predisposed to heat stress.

In other ginseng-growing areas, papery leaf spot has been associated with verticillium wilt. Heat stress symptoms can be confused with boron toxicity and calcium deficiency.

Air Pollution

Both ozone and sulphur dioxide can have an effect on ginseng leaves. Symptoms of air pollution in ginseng include bleached, whitened areas on the leaves (Plate 114, page 107). These areas are usually the size of a nickel but may be larger. They can occur at the base of the leaflets, in the middle of the leaflets along the main vein or at the leaflet tips. This same symptom can indicate herbicide damage due to drift. A check of surrounding weeds can usually rule out (or confirm) herbicide drift.

Boron Toxicity

Ginseng requires boron for growth and development, but too much can damage the plant. Excess boron can result in small root weight and even in a root condition similar to rusty root. The most obvious symptom of excess boron occurs on the leaves. The leaf edges will appear yellow or white and will dry out (Plate 22, page 92). If symptoms of boron toxicity appear in a garden, check fertility records to determine whether there may have been an application or measurement error. Boron toxicity can be confirmed by tissue analysis. Suspect toxicity when leaves contain more than 55 ppm boron.

Herbicide Drift

Occasionally, herbicide applied to neighbouring fields or in a perimeter area may drift onto a ginseng garden. If drift of a product containing glyphosate occurs in

the fall, even after the ginseng has senesced, there may be residue on the straw the following spring. This does not always occur, and environmental conditions play a role in such a carry-over. Symptoms may be visible in emerging plants in the spring as distorted strap-like leaves (Plate 115, page 108). If drift has occurred, there will be a discernible pattern to the area of damage. Damage can be confused with slug damage and with cold temperature damage. Analysis of the leaf tissue is the only way to know if herbicides have caused the symptoms.

Foliar Fertilizers Mixed With Fungicides

Dithane fungicides contain small amounts of zinc. If a foliar fertilizer containing zinc is added to the tank, leaf burn can result (Plate 116, page 108). Under warm or hot environmental conditions, the leaf injury can be severe enough to cause serious damage to the crop. Extensive leaf injury will result in smaller-than-average roots.

Foliar Fertilizers Containing Cytokinins

Some foliar fertilizers contain plant-based compounds called cytokinins. These are natural plant compounds that interfere with the growth hormones that promote elongation. If applied while the leaf canopy is still unfolding, they can have a distorting effect on the leaves and stems (Plate 117, page 108). Cytokinin damage may also leave the lower leaf surface thickened and shiny.

Low-Temperature and Freeze Damage

Low-temperature damage to ginseng is not uncommon in the early spring after emergence. Low, but not freezing, temperatures during the unfolding of the canopy may result in leaf puckering (Plate 118, page 108).

Freeze damage (when temperatures drop and remain below freezing) to ginseng is rare after emergence but can occur. Both the shade structure and the straw mulch act to moderate the temperature of the plant canopy. Once the soil begins to warm beneath the straw mulch, radiant energy acts to further mediate the climate of the crop canopy. Where freeze damage occurs, it appears to be worse under low cloth shade than under wooden lath shade. Research has shown that cool air masses that settle in low areas are less likely to dissipate through the cloth shade material than through wooden lath.

The extent of damage depends on the length of time the temperature remains below 0°C, on the soil temperature at the time of freezing and on the

shade material covering the garden. Gardens that are repeatedly exposed to freezing temperatures suffer greater damage.

Symptoms of freeze damage vary with the age of the garden.

Seedlings: Seedling gardens may be permanently damaged by freezing temperatures. Typical freeze damage consists of glassy, drooping leaves that turn black and decompose. Plants do not recover.

Older gardens: The most common symptom is sharply bent stems (Plate 119, page 108). Some plants may recover from this. Other symptoms include swollen and split stems (Plate 120, page 108), shrivelled stems below the flower head or just below the junction of the leaves, and browning of the developing flower buds.

Leaves on older plants may become glassy and droop. Under some conditions, plants may recover from this.

Recovery from split stems is unlikely. Two-year-old gardens appear to be especially susceptible to freeze damage. Recovery of plants from freeze damage in a two-year-old garden is in the range of 50%.

Low-temperature damage can also occur during the winter months when the plant is dormant. Research has indicated that temperatures under snow cover are moderated and rarely drop below -5°C at the crown of the root. The critical temperature for root survival during dormancy appears to be -11°C for seedlings and -16°C for older roots. Research has also shown that root damage can occur when soil temperatures drop below -6°C as indicated in the previous section on ginseng rust spot. Duration of the cold temperatures is also a factor. In light of this information, growers could expect damage to roots when temperatures drop below -6°C in open winters (winters with little snow cover) especially where the straw mulch is thin.

6. Pest Control Recommendations

Always read the label thoroughly before applying a pest control product and follow label instructions. See Chapter 1, *Using Pesticides in Ontario*, for a discussion of the safe use of pesticides.

Table 6-1. Ginseng Seed Treatments

Target Pest	Product	Product Rate	Active chemical	Notes
<i>Pythium</i>	Apron XL LS	20–40 mL per 100 kg seed	metalaxyl-M	Use in commercial seed-treatment plants only. Apply only once during the life of a garden as a seed treatment.

Table 6-2. Preplant Fumigation of Ginseng in Ontario

Target Pests	Product	Product Rate ¹	Chemical Name	Notes
nematodes	Telone ² II B	See label.	1,3-dichloropropene	See label.
nematodes, soil-borne diseases	Telone ² C-17-R	See label.	1,3-dichloropropene, chloropicrin	Use higher rates for disease control.
nematodes, soil-borne diseases, weeds	Vapam	550–900 L/ha	metam-sodium	Lower rates adequately control nematodes. Apply by soil injection.
	Vapam HL	410–670 L/ha		
nematodes, soil-borne diseases and weeds	Busan 1020	700–900 L/ha	metam-sodium	Lower rates adequately control nematodes. Apply by soil injection.
	Busan 1236	274–683 L/ha		
nematodes, soil-borne diseases and weeds	Basamid	325–500 kg/ha	dazomet	Apply as a granular with a spreader then incorporate immediately.

¹ For liquid fumigants, the product rates for Vapam and Busan listed are for soil injection. Consult the label for recommended product rates if other methods of application are used.

² Telone products will no longer be registered for use after November 30, 2011.

Table 6-3. Insect Control Recommendations for Ginseng in Ontario

Target Pest	Product	Product Rate	Chemical Name	Notes
Cutworms: army, black, pale, Western, red-backed, white, variegated	Pounce 384 EC	180–390 mL/ha	permethrin	Apply when scouting indicates the presence of cutworms. Ground application: Apply in sufficient water to give thorough coverage of the plants. Use the higher rate if the infestation is heavy. Under dry conditions, apply 295–390 mL/ha. Where worms are large (2.54 cm), use 295–390 mL/ha. Applications should be made under warm, moist conditions in the evening or at night. A maximum of 2 applications per year are permitted.
Four-lined plant bug	Pounce 384 EC	180–260 mL/ha	permethrin	Ground application: Pounce may be applied up to 40 days to harvest. A maximum of 2 applications per year are permitted.
Leaf rollers	Dipel 2X DF	565–1,125 g/ha in 760–1,250 L/ha water	<i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> Strain HD-1	A maximum of 2 applications per year are permitted. For best control, apply when larvae are small.
European chafer	Admire 240/ Alias 240 SC/ Grapple	1.2 L/ha in 200 L/ha water	imidacloprid	Ground application: Apply to newly seeded ginseng gardens before mulch is laid down. Avoid application to areas that are waterlogged or saturated. Sufficient irrigation (5–10 mm) is required within 24 hours of application to move the active ingredient to the root zone. More than 20 mm of irrigation/rainfall could wash chemical out of the root zone. Apply only once during the life of a ginseng garden. Allow 3 years between application of imidacloprid and harvest.

Weed Control in Ginseng

Good weed control depends on the timing of herbicide applications.

Check the label to find out which weeds are susceptible and at what growth stage treatment is most effective.

Table 6-4. Weed Control Recommendations for Ginseng in Ontario

Target Weeds	Product	Product Rate	Chemical Name	Notes
Spring prior to emergence of ginseng plants				
Annual weeds, perennial weeds	Many trade names available e.g., Roundup, Glyfos	Depends on the product used. Consult the product label.	glyphosate (present as diammonium, isopropylamine, potassium or dimethylamine salts)	New gardens: Glyphosate is not registered for application to new gardens in Ontario. Established gardens (seedling year and later): Apply in the spring before the crop has emerged above the soil. Apply when weeds are at the growth stage described on the label. DO NOT USE A FALL APPLICATION IN ESTABLISHED GARDENS. DO NOT EXCEED THE RATE OR SPRAY VOLUMES, OR CROP INJURY MAY RESULT. Glyphosate products are non-selective herbicides and may cause crop damage if in contact with actively growing ginseng foliage.
Post-emergence				
Grasses (see label)	Venture L	Maximum of: 2 L/ha at any single application	fluazifop-P-butyl and S-isomer	A maximum of 3 applications per year are permitted. Apply in early May, late June, mid-August. Use ground application only. Do not apply in the year of harvest.

Table 6-5. Slug Control Recommendations for Ginseng in Ontario

Target Pest	Product	Product Rate	Active chemical	Notes
Slugs and snails including, but not limited to: field slugs, smooth slug, dusky slug, grey garden slug, black field slug, large red slug, large black slug, spotted garden slug, slender slug, banana slug and <i>Helix</i> , <i>Helicella</i> and <i>Cepaea</i> spp.	Sluggo Snail and Slug Bait	25–50 kg/ha	iron phosphate	Bait may be broadcast with conventional broadcast applicators. Apply at the higher rate if infestation is severe, if the area is heavily watered or after heavy rains. Reapply as the bait is consumed or every 2 weeks. Do not place in piles. Sluggo Snail and Slug Bait is best applied to moist soil.

Table 6-6. Disease Control Recommendations for Ginseng in Ontario

Target Pest	Product	Product Rate	Active Chemical	Notes
Rhizoctonia	Quadris	Apply 1.12 L Quadris Flowable/ha on newly seeded gardens in the fall before application of the straw mulch Apply 1.12 L Quadris Flowable/ha in the spring of the first year pre-emergent to the ginseng over the straw mulch.	azoxystrobin	For best control of rhizoctonia, apply Quadris Flowable in 4,000 L water/ha. Do not apply within 24 months of harvest. A maximum of 2 applications is permitted in the life of a garden. CAUTION: Quadris Flowable Fungicide can be extremely toxic to certain varieties of apples and crabapples. Do not apply where there is a possibility of spray drift reaching apple or crabapple trees. Do not use sprayers used to apply Quadris Flowable Fungicide to spray apples or crabapples.
Phytophthora root rot ¹	Ridomil Gold 1G	31.25 kg/ha	metalaxyl-M	Apply uniformly as a broadcast application. Make one application in the spring just prior to the time the plants begin growing. Make a second application 6 weeks later and a third application 6 weeks after the second one. Do not apply within 9 days of harvest. Do not make more than 3 applications per year. Do not apply other products containing metalaxyl-M to ginseng. See <i>Fungicide Resistance</i> , on page 62.
	Aliette WDG	5.5 kg/ha in a minimum of 200 L/ha water	fosetyl al	Make the first application between the first two Ridomil applications. Repeat up to 3 times through the season depending on the weather. Make the final application prior to senescence when there is 50% green in the foliage. Do not apply within 31 days of harvest. Do not apply Aliette more than 5 times in one season. Do not use with a spreader/sticker. See <i>Fungicide Resistance</i> , on page 62.
Phytophthora leaf blight	Aliette WDG	5.5 kg/ha in a minimum of 200 L/ha water	fosetyl al	Apply when symptoms first appear. Do not apply Aliette more than 5 times in one season. Do not apply within 31 days of harvest. Do not use with a spreader/sticker. See <i>Fungicide Resistance</i> , on page 62.

Table 6-6. Disease Control Recommendations for Ginseng in Ontario

Target Pest	Product	Product Rate	Active Chemical	Notes
Alternaria leaf blight	Dithane M-45	4.4 kg/ha in 2,000 L/ha water	mancozeb ^{2,3}	Apply when disease first appears. Do not apply within 30 days of harvest.
	Dithane DG Rainshield NT	4.4 kg/ha in 2,000 L/ha water	mancozeb ^{2,3}	Apply when disease first appears. Do not apply within 30 days of harvest.
	Dithane F-45	7.3 L/ha in 2,000 L/ha water	mancozeb ^{2,3}	Apply when disease first appears. Do not apply within 30 days of harvest.
	Penncozeb 75 DF	4.4 kg/ha in 2,000 L/ha water	mancozeb ^{2,3}	Apply when disease first appears. Do not apply within 30 days of harvest. Do not feed ginseng foliage to livestock.
	Penncozeb 80 WP	4.4 kg/ha in 2,000 L/ha water	mancozeb ^{2,3}	Apply when disease first appears. Do not apply within 30 days of harvest. Do not feed ginseng foliage to livestock.
	Manzate Pro- Stick DF	4.4 kg/ha in 2,000 L/ha water	mancozeb ^{2,3}	Apply when disease first appears. Do not apply within 30 days of harvest. Do not feed treated ginseng (roots or foliage) to livestock.
	Rovral	1.1 kg/ha in at least 2,000 L/ha water	iprodione ²	Do not apply within 30 days of harvest. Do not apply more than 3 times throughout the season. Alternate with Bravo and mancozeb.
	Bravo 500F	2.4–4.8 L/ha	chlorothalonil ²	Do not apply within 14 days of harvest. Do not apply more than 6 times throughout the season. Alternate with mancozeb and Rovral.
Botrytis	Bravo 500F	2.4–4.8 L/ha	chlorothalonil	Do not apply within 14 days of harvest. Do not apply more than 6 times throughout the season.
	Elevate 50 WDG	1.7 kg/ha	fenhexamid	Apply at 10–14-day intervals. Do not apply more than 4 times throughout the season. Apply prior to disease establishment when conditions are favourable for disease development. Applications can be made up to the day of harvest. Alternate with Bravo.

¹ See *Phytophthora Root Rot and Blight of Ginseng*, on page 52, for an integrated phytophthora control program.

² Do not apply more than 6 sprays containing mancozeb per season.

³ Products containing mancozeb should be alternated with Bravo and Rovral as part of a resistance management program.

Ontario Emergency Use Registrations

Products that are registered as Emergency Use are not listed in these recommendations because they are only registered for limited periods of time. For an up-to-date list of Emergency Use Registrations for ginseng, consult the OMAFRA website at www.ontario.ca/crops and click on Minor Use Program under the Pest Management and Minor Use section.

7. Appendices

Appendix A.

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Specialty Crop Advisory Staff

Sean Westerveld
Ginseng and Medicinal Herbs Specialist
P.O. Box 587
Blueline Rd. & Hwy #3
Simcoe, ON N3Y 4N5
Tel: 519-426-4323
Fax: 519-428-1142
E-mail: sean.westerveld@ontario.ca

Melanie Filotas
IPM Specialist – Specialty Crops
P.O. Box 587
Blueline Rd. & Hwy #3
Simcoe, ON N3Y 4N5
Tel: 519-426-4434
Fax: 519-428-1142
E-mail: melanie.filotas@ontario.ca

Evan Elford
New Crop Development Specialist
P.O. Box 587
Blueline Rd. & Hwy #3
Simcoe, ON N3Y 4N5
Tel: 519-426-4509
Fax: 519-428-1142
E-mail: evan.elford@ontario.ca

Jim Todd
Transition Crop Specialist
P.O. Box 587
Blueline Rd. & Hwy #3
Simcoe, ON N3Y 4N5
Tel: 519-426-3823
Fax: 519-428-1142
E-mail: jim.todd@ontario.ca

A complete list of Ontario Ministry of Agriculture, Food and Rural Affairs advisory staff is available on the OMAFRA website at www.ontario.ca/crops.

Agricultural Information Contact Centre

Provides province-wide, toll-free technical and business information to commercial farms, agri-businesses and rural businesses.

1 Stone Rd. W.
Guelph, ON N1G 4Y2

Tel: 519-826-4047
Toll-free: 1-877-424-1300
Fax: 519-826-7610
E-mail: ag.info.omafra@ontario.ca

Appendix B. Diagnostic Service

Samples for disease diagnosis, insect or weed identification, nematode counts and *Verticillium* testing can be sent to:

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Rd. W.
Guelph, ON N1H 8J7

Tel: 519-767-6256
Fax: 519-767-6240
E-mail: pdclsd@uoguelph.ca

Payment must accompany samples at the time of submission. Submission forms are available at: www.labservices.uoguelph.ca/units/pdc/.

FEE SCHEDULE

To obtain information on the fee schedule, visit www.labservices.uoguelph.ca/units/pdc/ or phone the Pest Diagnostic Clinic.

HOW TO SAMPLE FOR NEMATODES

Soil

When to Sample

Soil and root samples can be taken at any time of the year that the soil is not frozen. In Ontario, nematode soil population levels are generally at their highest in May and June and again in September and October.

How to Sample Soil

Use a soil sampling tube, trowel or narrow-bladed shovel to take samples. Sample soil to a depth of 20–25 cm (8–10 in.). If the soil is bare, remove the top 2 cm (1 in.) prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of 0.5–1 L (1 pint–1 quart) from this. No single sample should represent more than 2.5 ha (6.25 acre). Mix subsamples in a clean pail or plastic bag.

Sampling Pattern

If living crop plants are present in the sample area, take samples within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of Subsamples

Based on the total area sampled:

500 m ² (5,400 ft ²)	10 subsamples
500 m ² –0.5 ha (5,400 ft ² –1.25 acres)	25 subsamples
0.5 ha–2.5 ha (1.25–6.25 acres)	50 subsamples

Roots

For small plants, sample the entire root system plus adhering soil. For large plants, dig 10–20 g (1/2–1 oz.) fresh weight from the feeder root zone and submit.

Problem Areas

Take soil and root samples from the margins of the problem area where the plants are still living. If possible, also take samples from healthy areas in the same field. If possible, take both soil and root samples from problem and healthy areas in the same field.

SAMPLE HANDLING

Soil Samples

Place in plastic bags as soon as possible after collecting.

Root Samples

Place in plastic bags and cover with moist soil from the sample area.

Storage

Store samples at 5°C–10°C (40°F–50°F) and do not expose them to direct sunlight or extreme heat or cold (freezing). Only living nematodes can be counted. Accurate counts depend on proper handling of samples.

SUBMITTING PLANT FOR DISEASE DIAGNOSIS OR IDENTIFICATION

Sample Submission Forms

Forms can be obtained from your local Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) office. Carefully fill in all of the categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past 3 years and pesticide use records from this year.

Choose a complete, representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system, or several plants showing a range of symptoms. If symptoms are general, collect the sample from an area where they are of intermediate severity. Completely dead material is usually inadequate for diagnosis.

With plant specimens submitted for identification, include at least a 20–25-cm sample of the top portion of the stem with lateral buds, leaves, flowers or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid the soil drying out and contaminating the leaves. Do not add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping. Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery

Deliver to the Pest Diagnostic Clinic as soon as possible by first class mail or courier at the beginning of the week.

SUBMITTING INSECT SPECIMENS FOR IDENTIFICATION

Collecting Samples

Place dead, hard-bodied insects in vials or boxes and cushion with tissues or cotton. Place soft-bodied insects and caterpillars in vials containing alcohol. Do not use water, as this results in rot. Do not tape insects to paper or send them loose in an envelope.

Place live insects in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.



95 Stone Road West
Guelph, ON N1H 8J7
Tel: (519) 767-6256
Fax: (519) 767-6240
Web: www.uoguelph.ca/pdc

Pest Diagnostic Clinic

SAMPLE SUBMISSION FORM

LABORATORY USE ONLY: LS Form: SubP01/04/03 Pg. 1 of 1

Rec'd: By: _____ Date Received: _____

Delivered By: ☐ Mail ☐ Courier ☐ In-Person

LS Sample No: _____ to _____

Payment Rec'd: \$ _____ Receipt #: _____

Submitted By: _____ Owner (if different from submitter): _____

Business Name (if applicable): _____ Business Name (if applicable): _____

Street: _____ Street: _____

City: _____ Prov: _____ Postal Code: _____ City: _____ Prov: _____ Postal Code: _____

Tel: () - _____ Fax: () - _____ Tel: () - _____ Fax: () - _____

Email: _____ Email: _____

Unless otherwise indicated, report and invoice will be sent to submitter

Report to: ☐ Submitter ☐ Owner Required Report Format: ☐ Fax ☐ E-Mail ☐ Mail

Invoice to: ☐ Submitter ☐ Owner Quotation #: _____ Purchase Order / U of G G/L code: _____

Services Required: ☐ Nematode Count ☐ Nematode Count from Roots ☐ SCN Cyst & Egg Count
☐ Plant Disease Diagnosis ☐ Insect Identification ☐ Plant Identification ☐ Verticillium Count

Plant or Host Affected: _____ Cultivar/Variety: _____ Grower/Field sample #: _____

Location of Plant (i.e. greenhouse, field, orchard, garden, etc.): _____

Size of Planting: _____ % of Plants Affected: _____ Symptoms First Appeared in Past: _____ Degree of Injury: _____
☐ Days ☐ Weeks ☐ Months ☐ Years ☐ Severe ☐ Moderate ☐ Light

Cropping History: _____ Future Crop: _____

Describe the problem in detail (i.e. symptoms, plant parts affected, distribution of symptoms):

Were chemicals applied? Please specify type of product(s) used and date(s) of application:

Additional comments and specific requests:

Additional Sheet(s) Attached: ☐

Appendix C.

Phytosanitary Certificates

Phytosanitary certificates may be required by importing countries. A phytosanitary certificate is a certificate indicating that a shipment is free from recognized or quarantinable pests. Countries importing ginseng seed may require a phytosanitary certificate. The importing country will list the pests or conditions associated with certification. If you are shipping ginseng seed or living roots out of Canada, it is best to check with the importing country to determine what rules, if any, may affect your shipment. Knowing the rules in advance will avoid situations where your perishable crop may be held up before entry.

Phytosanitary certificates can be obtained through the Canadian Food Inspection Agency (CFIA) at one of the regional offices listed in Appendix D. *Other Contacts*, opposite page.

Appendix D. Other Contacts

AGRICULTURE & AGRI-FOOD CANADA RESEARCH-CENTRES

www.agr.ca/index_e.php

Eastern Cereals and Oilseeds
Research Centre
960 Carling Ave.
Ottawa, ON K1A 0C6
Tel: 613-759-1858

Greenhouse and Processing
Crops Centre
2585 County Road 20
Harrow, ON N0R 1G0
Tel: 519-738-2251

Southern Crop Protection and
Food Research Centre
1391 Sandford St.
London, ON N5V 4T3
Tel: 519-457-1470

Vineland Research Farm
4902 Victoria Ave. N.
Vineland, ON L0R 2E0
Tel: 905-562-4113

Delhi Research Farm
Box 186 Schafer Road
Delhi, ON N4B 2W9
Tel: 519-582-1950

VINELAND RESEARCH AND INNOVATION CENTRE

www.vinelandontario.ca

4890 Victoria Ave. N.
Lincoln, ON L0R 2E0
Tel: 905-562-0320
Fax: 905-562-0084

CANADIAN FOOD INSPECTION AGENCY REGIONAL OFFICES (PLANT PROTECTION)

www.inspection.gc.ca/english/toce.shtml

Belleville
345 College St. E.
Belleville, ON K8N 5S7
Tel: 613-969-3333

Brantford
625 Park Rd. N., Suite 6
Brantford, ON N3T 5P9
Tel: 519-753-3478

Hamilton
709 Main St. W., Ste. 101
Hamilton, ON L8S 1A2
Tel: 905-572-2201

London
19-1200 Commissioners Rd. E.
London, ON N5Z 4R3
Tel: 519-691-1300

Niagara Falls
350 Ontario St., Unit 13
P.O. Box 9
St. Catharines, ON L2R 5L8
Tel: 905-357-5981

Ottawa District
38 Auriga Dr., Unit 8
Ottawa, ON K2E 8A5
Tel: 613-274-7374, ext 221

Toronto
1124 Finch Ave. W., Unit 2
Downsview, ON M3J 2E2
Tel: 416-665-5055

UNIVERSITY OF GUELPH

Main Campus
Guelph, ON N1G 2W1
Tel: 519-824-4120
www.uoguelph.ca

Alfred Campus
Alfred, ON K0B 1A0
Tel: 613-679-2218
Fax: 613-679-2423
www.alfredc.uoguelph.ca

Kemptville Campus
Kemptville, ON K0G 1J0
Tel: 613-258-8336
Fax: 613-258-8384
www.kemptvillec.uoguelph.ca

Ridgetown Campus
Ridgetown, ON N0P 2C0
Tel: 519-674-1500
www.ridgetownc.on.ca

Department of Plant Agriculture

www.plant.uoguelph.ca

Guelph
50 Stone Rd. E.
Guelph, ON N1G 2W1
Tel: 519-824-4120,
ext. 56083 or 52693
Fax: 519-763-8933

Simcoe
1283 Blueline Rd., Box 587
Simcoe, ON N3Y 4N5
Tel: 519-426-7127
Fax: 519-426-1225

Vineland
Box 7000, 4890 Victoria Ave. N.
Vineland Station, ON L0R 2E0
Tel: 905-562-4141
Fax: 905-562-3413

Lab Services Division

www.uoguelph.ca/labserv/

95 Stone Rd. W.
Guelph, ON N1H 8J7

Trace Organic and Pesticide
Contaminants
Tel: 519-823-1268

Pest Diagnostic Clinic
Tel: 519-767-6256

Appendix E. Accredited Soil Testing Labs in Ontario

The following labs are accredited to perform soil tests for pH, buffer pH, P, K, Mg and Nitrate-N on Ontario soils. There is no official accreditation in Ontario for tissue analysis, but all the accredited soil testing labs are monitored for proficiency on tissue analyses.

Laboratory Name	Address	Telephone/Fax	Contact
A & L Canada Laboratories Inc.	2136 Jetstream Rd. London, ON N5V 3P5	Tel: 519-457-2575 Fax: 519-457-2664 E-mail: aginfo@alcanada.com	Greg Patterson Ian McLachlin
Accutest Laboratories A Bodycote Testing Group Company	8-146 Colonnade Rd. Ottawa, ON K2E 7Y1	Tel: 613-727-5692, x.317 Fax: 613-727-5222 E-mail: lorna.wilson@bodycote.com	Lorna Wilson
Agri-Food Laboratories	503 Imperial Rd., Unit #1 Guelph, ON N1H 6T9	Tel: 519-837-1600 1-800-265-7175 Fax: 519-837-1242 E-mail: lab@agtest.com	Trish Kelly Jack Legg
Brookside Laboratories, Inc.	308 South Main Street New Knoxville, Ohio 45871	Tel: 419-753-2448 Fax: 419-753-2949 E-mail: jbrackman@blinc.com	Jackie Brackman Mark Flock
FoReST Laboratory	955 Oliver Rd. BB1005D Thunder Bay, ON P7B 5E1	Tel: 807-343-8639 Fax: 807-343-8116 E-mail: soilslab@lakeheadu.ca	Claire Riddell Joel Symonds
University of Guelph, Laboratory Services	University of Guelph P.O. Box 3650 95 Stone Rd. W. Guelph, ON N1H 8J7	Tel: 519-767-6299 Fax: 519-767-6240 E-mail: info@lsd.uoguelph.ca	Nick Schrier
Stratford Agri-Analysis	1131 Erie St. Box 760 Stratford, ON N5A 6W1	Tel: 519-273-4411 1-800-323-9089 Fax: 519-273-2163 E-mail: info@stratfordagri.ca	Keith Lemp Mark Aikman

Appendix F

Ontario Ministry of the Environment Regional Contact Information

Central Region Toronto, Halton, Peel, York, Durham, Muskoka, Simcoe	5775 Yonge St, 8th Floor Toronto, ON M2M 4J1	Tel: 416-326-6700 Toll-free: 1-800-810-8048 Fax: 416-325-6345
West-Central Region Haldimand, Norfolk, Niagara, Hamilton- Wentworth, Dufferin, Wellington, Waterloo, Brant	Ontario Government Building 119 King St. W., 12th Floor Hamilton, ON L8P 4Y7	Tel: 905-521-7640 Toll-free: 1-800-668-4557 Fax: 905-521-7820
Eastern Region Frontenac, Hastings, Lennox & Addington, Prince Edward, Leeds & Grenville, Prescott & Russell, Stormont/ Dundas & Glengarry, Haliburton, Peterborough, Kawartha Lakes, Northumberland, Renfrew, Ottawa, Lanark, District of Nipissing (Twp. of South Algonquin)	1259 Gardiners Rd., Unit 3, PO Box 22032 Kingston, ON K7M 8S5	Tel: 613-549-4000 Toll-free: 1-800-267-0974 Fax: 613-548-6908
Southwestern Region Elgin, Middlesex, Oxford, Essex, Kent, Lambton, Bruce, Grey, Huron, Perth	733 Exeter Rd., 2nd Floor London, ON N6E 1L3	Tel: 519-873-5000 Toll-free: 1-800-265-7672 Fax: 519-873-5020
Northern Region (east) Manitoulin, Nipissing, Parry Sound, Algoma (East), Timiskaming, Sault Ste. Marie	199 Larch St., Suite 1201 Sudbury, ON P3E 5P9	Tel: 705-564-3237 Toll-free: 1-800-890-8516 Fax: 705-564-4180
Northern Region (west) Algoma (West), Cochrane, Kenora, Rainy River, Timmins, Thunder Bay	435 James St. S., Suite 331 Thunder Bay, ON P7E 6S7	Tel: 807-475-1205 Toll-free: 1-800-875-7772 Fax: 807-475-1754
Standards Development Branch	Pesticides Section 40 St. Clair Ave. W., 7th Floor Toronto, ON M4V 1M2	Tel: 416-327-5519 Fax: 416-327-2936
Approvals Branch	Pesticides Licensing 2 St. Clair Ave. W., 12A Floor Toronto, ON M4V 1L5	Tel: 416-314-8001 Toll-free: 1-800-461-6290 Fax: 416-314-8452

Appendix G. The Metric System

METRIC UNITS

Linear Measures (length)

10 millimetres (mm)	= 1 centimetre (cm)
100 centimetres (cm)	= 1 metre (m)
1,000 metres (m)	= 1 kilometre (km)

Square Measures (area)

100 m x 100 m = 10,000 m ²	= 1 hectare (ha)
100 hectares	= 1 square kilometre (km ²)

Cubic Measures (volume)

Dry Measure

1,000 cubic millimetres (mm ³)	= 1 cubic centimetre (cm ³)
1,000,000 cubic centimetres (cm ³)	= 1 cubic metre (m ³)

Liquid Measure

1,000 millilitres (mL)	= 1 litre (L)
100 litres (L)	= 1 hectolitre (hL)

Weight-Volume Equivalents (for water)

(1.00 kg) 1,000 grams	= 1 litre (1.00 L)
(0.50 kg) 500 grams	= 500 millilitres (0.50 L)
(0.10 kg) 100 grams	= 100 millilitres (0.10 L)
(0.01 kg) 10 grams	= 10 millilitres (0.01 L)
(0.001 kg) 1 gram	= 1 millilitre (0.001 L)

Weight Measures

1,000 milligrams (mg)	= 1 gram (g)
1,000 grams (g)	= 1 kilogram (kg)
1,000 kilograms (kg)	= 1 tonne (t)
1 milligram/kilogram	= 1 part per million (ppm)

Dry-Liquid Equivalents

1 cubic centimetre (cm ³)	= 1 millilitre (mL)
1 cubic metre (m ³)	= 1,000 litres (L)

APPLICATION RATE CONVERSIONS

Metric to Imperial or US (Approximate)

litres per hectare x 0.09	= gallons per acre
litres per hectare x 0.36	= quarts per acre
litres per hectare x 0.71	= pints per acre
millilitres per hectare x 0.015	= fluid ounces per acre
grams per hectare x 0.015	= ounces per acre
kilograms per hectare x 0.89	= pounds per acre
tonnes per hectare x 0.45	= tons per acre

Imperial or US to Metric (Approximate)

gallons per acre x 11.23	= litres per hectare (L/ha)
quarts per acre x 2.8	= litres per hectare (L/ha)
pints per acre x 1.4	= litres per hectare (L/ha)
fluid ounces per acre x 70	= millilitres per hectare (mL/ha)
tons per acre x 2.24	= tonnes per hectare (t/ha)
pounds per acre x 1.12	= kilograms per hectare (kg/ha)
ounces per acre x 70	= grams per hectare (g/ha)

Metric Conversions

5 mL	= 1 tsp
15 mL	= 1 tbsp
28.5 mL	= 1 fl. oz

DRY WEIGHT EQUIVALENTS

Metric	Imperial
100 grams/hectare (g/ha)	= 1½ ounces/acre (oz/acre)
200 grams/hectare (g/ha)	= 3 ounces/acre (oz/acre)
300 grams/hectare (g/ha)	= 4¼ ounces/acre (oz/acre)
500 grams/hectare (g/ha)	= 7 ounces/acre (oz/acre)
700 grams/hectare (g/ha)	= 10 ounces/acre (oz/acre)
1.10 kilograms/hectare (kg/ha)	= 1 pound/acre (lb/acre)
1.50 kilograms/hectare (kg/ha)	= 1¾ pounds/acre (lb/acre)
2.00 kilograms/hectare (kg/ha)	= 1¾ pounds/acre (lb/acre)
2.50 kilograms/hectare (kg/ha)	= 2¼ pounds/acre (lb/acre)
3.25 kilograms/hectare (kg/ha)	= 3 pounds/acre (lb/acre)
4.00 kilograms/hectare (kg/ha)	= 3½ pounds/acre (lb/acre)
5.00 kilograms/hectare (kg/ha)	= 4½ pounds/acre (lb/acre)
6.00 kilograms/hectare (kg/ha)	= 5¼ pounds/acre (lb/acre)
7.50 kilograms/hectare (kg/ha)	= 6¾ pounds/acre (lb/acre)
9.00 kilograms/hectare (kg/ha)	= 8 pounds/acre (lb/acre)
11.00 kilograms/hectare (kg/ha)	= 10 pounds/acre (lb/acre)
13.00 kilograms/hectare (kg/ha)	= 11½ pounds/acre (lb/acre)
15.00 kilograms/hectare (kg/ha)	= 13½ pounds/acre (lb/acre)

LIQUID EQUIVALENTS

Litres/Hectare		Approximate Gallons/Acre
50	=	5
100	=	10
150	=	15
200	=	20
250	=	25
300	=	30

ABBREVIATIONS

%	= per cent (by weight)	km/h	= kilometres per hour
ai	= active ingredient	kPa	= kilopascal
AP	= agricultural powder	L	= litre
cm	= centimetre	m	= metre
cm ²	= square centimetre	m/sec	= metres per second
DG	= dispersible granular	m ²	= square metre
DP	= dispersible powder	mL	= millilitre
E	= emulsifiable	mm	= millimetre
e.g.	= for example	SC	= sprayable concentrate
EC	= emulsifiable concentrate	SP	= soluble powder
F	= flowable	t	= tonne
g	= gram	W	= wettable (powder)
Gr	= granules, granular	WDG	= water dispersible granular
ha	= hectare	WP	= wettable powder
kg	= kilogram	km/h	= kilometres per hour

Appendix G. The Metric System (continued)

CONVERSION TABLES — METRIC TO IMPERIAL

Length	
1 millimetre (mm)	= 0.04 inch (in.)
1 centimetre (cm)	= 0.40 inch (in.)
1 metre (m)	= 39.40 inches (in.)
1 metre (m)	= 3.28 feet (ft)
1 metre (m)	= 1.09 yards (yd)
1 kilometre (km)	= 0.62 mile (mi)
Area	
1 square centimetre (cm ²)	= 0.16 square inch (in. ²)
1 square metre (m ²)	= 10.77 square feet (ft ²)
1 square metre (m ²)	= 1.20 square yards (yd ²)
1 square kilometre (km ²)	= 0.39 square mile (mi ²)
1 hectare (ha)	= 107,636 square feet (ft ²)
1 hectare (ha)	= 2.5 acres (acre)
Volume (dry)	
1 cubic centimetre (cm ³)	= 0.061 cubic inch (in. ³)
1 cubic metre (m ³)	= 1.31 cubic yards (yd ³)
1 cubic metre (m ³)	= 35.31 cubic feet (ft ³)
1,000 cubic metres (m ³)	= 0.81 acre-foot
1 hectolitre (hL)	= 2.8 bushels (bu)
Volume (liquid)	
1 millilitre (mL)	= 0.035 fluid ounce (Imp)
1 litre (L)	= 1.76 pints (Imp)
1 litre (L)	= 0.88 quart (Imp)
1 litre (L)	= 0.22 Imperial gallons (gal)
1 litre (L)	= 0.26 U.S. gallon (U.S. gal)
Weight	
1 gram (g)	= 0.035 ounce (oz.)
1 kilogram (kg)	= 2.21 pounds (lb)
1 tonne (t)	= 1.10 short tons
1 tonne (t)	= 2,205 pounds (lb)
Pressure	
1 kilopascal (kPa)	= 0.15 pounds/square inch (lb/in. ²)
Speed	
1 metre per second (m/sec)	= 3.28 feet per second (ft/sec)
1 metre per second (m/sec)	= 2.24 miles per hour (mph)
1 kilometre per hour (km/h)	= 0.62 mile per hour (mph)
Temperature	
°F	= (°C × 9/5) + 32

CONVERSION TABLES — IMPERIAL TO METRIC

Length	
1 inch (in.)	= 2.54 centimetres (cm)
1 foot (ft)	= 0.30 metre (m)
1 yard (yd)	= 0.91 metre (m)
1 mile (mi)	= 1.61 kilometre (km)
Area	
1 square foot (ft ²)	= 0.09 square metres (m ²)
1 square yard (yd ²)	= 0.84 metre (m ²)
1 acre (ac)	= 0.40 hectare (ha)
Volume (dry)	
1 cubic yard (yd ³)	= 0.76 cubic metre (m ³)
1 bushel (bu)	= 36.37 litres (L)
Volume (liquid)	
1 fluid ounce (Imp.)	= 28.41 millilitres (mL)
1 pint (Imp.)	= 0.57 litre (L)
1 gallon (Imp.)	= 4.55 litres (L)
1 gallon (U.S.)	= 3.79 litres (L)
Weight	
1 ounce (oz)	= 28.35 grams (g)
1 pound (lb)	= 453.6 grams (g)
1 ton	= 0.91 tonne (t)
Pressure	
1 pound per square inch (lb/in ²)	= 6.90 kilopascals (kPa)
Temperature	
°C	= (°F-32) × 5/9

8. Colour Plates

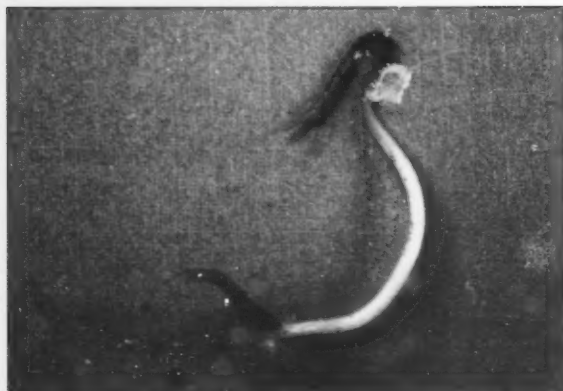


Plate 1. The emerging root and shoot of a ginseng seed.



Plate 2. Buds on a 4-year-old ginseng root. Note the secondary buds that are smaller than the primary bud. Secondary buds seldom sprout.



Plate 3. Two-year-old ginseng emerging through the straw mulch in the spring.



Plate 4. Ginseng seedlings after the leaves have unfolded in the spring.

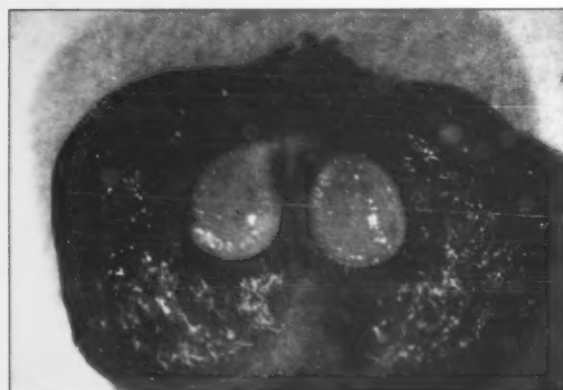


Plate 5. Developing ginseng seeds inside a green berry.



Plate 6. Ripe ginseng berries harvested into bushel baskets.



Plate 7. Ginseng plants showing the first flush of ripe berries ready to harvest.

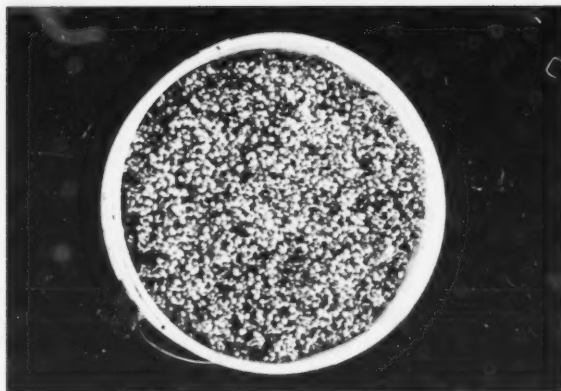


Plate 8. A tub of "green seeds" after depulping.



Plate 9. An immature ginseng embryo. This embryo is well developed and has already undergone partial stratification.



Plate 10. Stratified ginseng seeds. Note the variation in size.

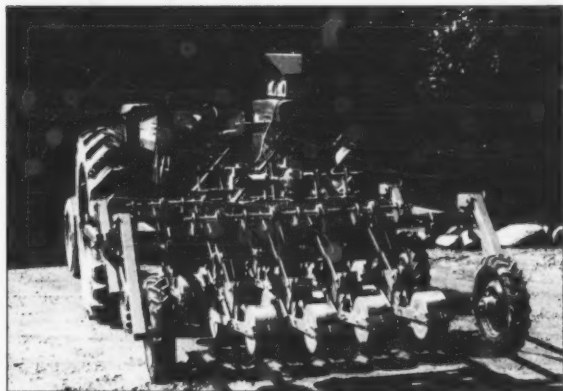


Plate 11. High-precision air seeder.



Plate 12. Formation of raised beds before planting ginseng.



Plate 13. Straw being applied to newly seeded ginseng beds.



Plate 14. Shrivelled flower stalks that have been infected with *Alternaria*.

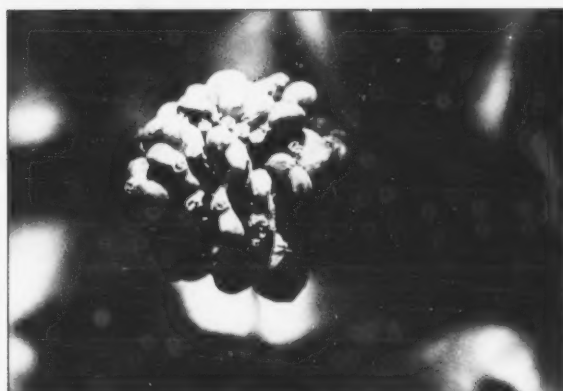


Plate 15. Berries infected with *Botrytis* often take on a purple colour.



Plate 16. As *Botrytis* infection progresses, the fungus forms masses of grey conidia that give the berries a fuzzy appearance.



Plate 17. A stand of wild ginseng in an Ontario forest.

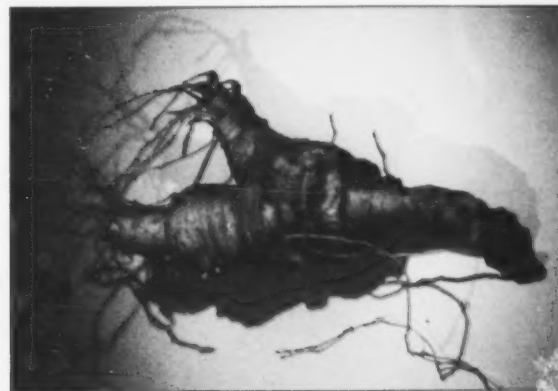


Plate 18. A wild ginseng root. Note the rhizome with bud scars from each year's growth. This particular root was about 23 years old.



Plate 19. A perimeter trench for the removal of surface water in a ginseng garden.



Plate 20. A path of missing plants that have been destroyed by phytophthora. This is a natural waterflow area through this garden.



Plate 21. Water standing in trenches in a ginseng garden that was not landscaped for surface water removal.



Plate 22. These plants are suffering from boron toxicity. Note the bleached and drying leaf edges. Research has shown that boron concentrations greater than 55 ppm in the leaves can be toxic.

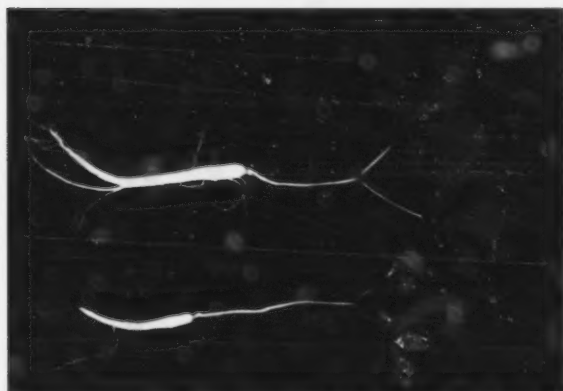


Plate 23. Compare the healthy plant above with the smaller plant affected by rye allelopathy below.



Plate 24. A nurse crop of oats in a newly seeded ginseng garden.



Plate 25. A ginseng garden with wooden lath shade.



Plate 26. A ginseng garden with low cloth shade.



Plate 27. A ginseng garden with high cloth shade.



Plate 28. A mechanical depulper used to remove the pulp from harvested ginseng berries.

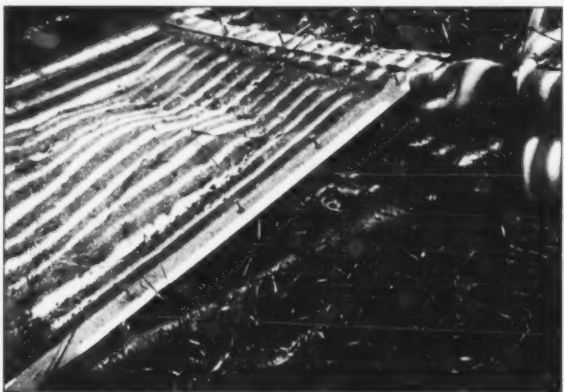


Plate 29. Checking the seed in a buried seedbox. The top of the box will be several feet below the soil surface.

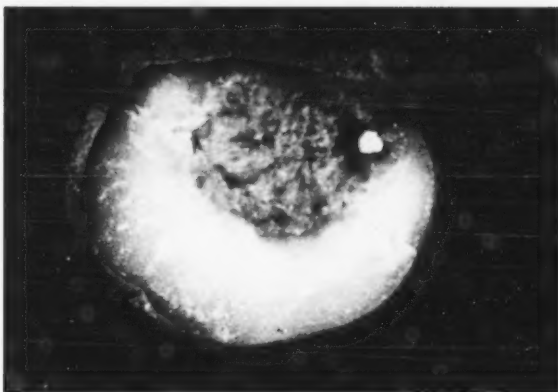


Plate 30. Infected seed showing a decayed area around the embryo.



Plate 31. A rust spot in the seed interior indicates that infection is present.



Plate 32. Pink fruiting bodies associated with *Cylindrocarpon* seed infection.



Plate 33. *Pythium* usually leaves the seed interior with a cheesy texture.



Plate 34. Bacterial seed decay often leaves the seed interior milky or blackened. A liquefied interior is associated with bacterial rot.



Plate 35. Note the drop of liquid oozing from the micropore. This will contain millions of bacteria.

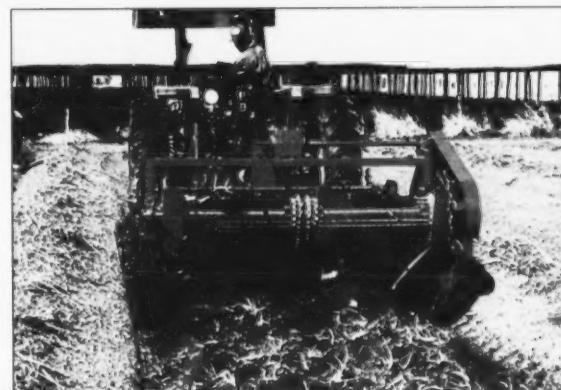


Plate 36. Ginseng roots are lying on the soil surface after being dug by a modified potato digger.



Plate 37. Harvested root is packed in baskets or bins and placed in refrigerated units for "conditioning."

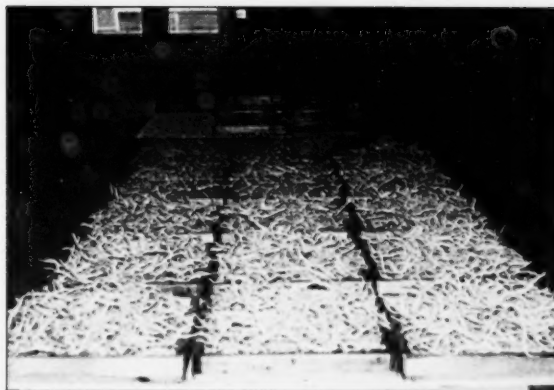


Plate 38. Washed roots are placed on drying trays after conditioning.



Plate 39. Drying trays are stacked in dryers so air can circulate freely.



Plate 40. An open ginseng dryer showing the trays stacked inside.



Plate 41. A dried ginseng root with a creamy interior.

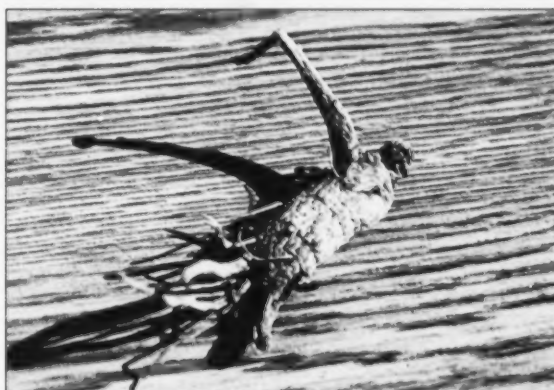


Plate 42. Note the red veins running vertically along this dried root.

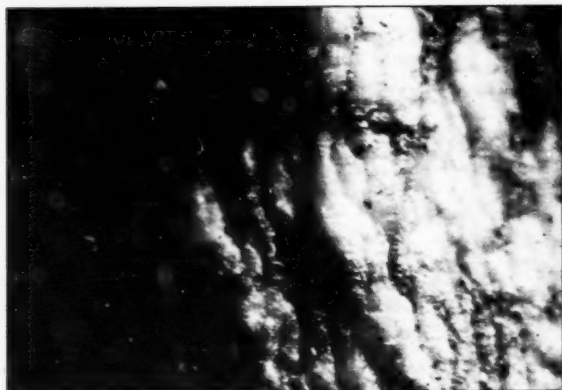


Plate 43. A close look at the red veins shows how close to the surface they are.



Plate 44. In this cross-section, the red veins can be seen as distinct canals just beneath the root surface.



Plate 45. The dark areas on this root are typical of *Rhizopus* infection, which can occur where there are pockets of high humidity during drying.

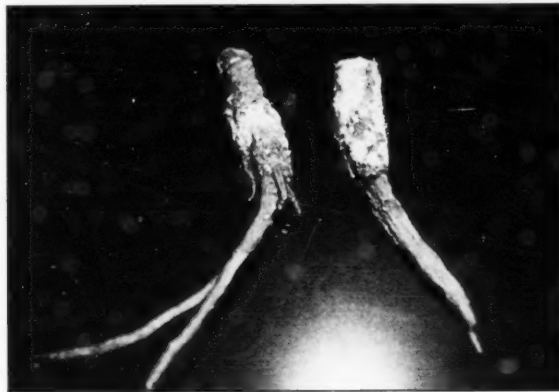


Plate 46. Geotrichum mould forms a dirty-white, fuzzy growth on the root surface as it dries, when humidity is excessive.



Plate 47. Damping-off occurs after ginseng seedlings have emerged through the straw. Plants suddenly collapse. They will quickly decompose.



Plate 48. These 3-year-old roots have *Pythium* infections on the small feeder roots. The feeder root tips are typically swollen and brown.



Plate 49. A soft rot of the tip of the taproot usually indicates infection by *Pythium*.



Plate 50. Buds invaded by *Pythium* at the time of emergence will develop a soft rot. The stem will break at the point of infection.



Plate 51. When feeder roots have been severely pruned, the uptake of water and nutrients will be impaired.

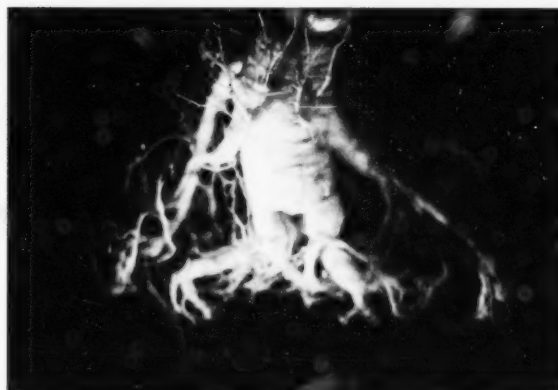


Plate 52. Another typical symptom of *Pythium* infection is the proliferation of feeder roots when the root attempts to compensate for the loss of its ability to take up water.

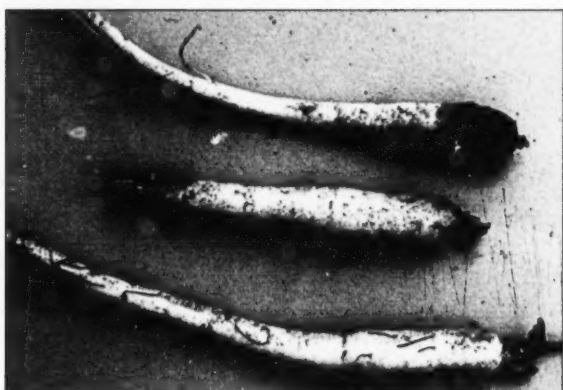


Plate 53. Three examples of *Rhizoctonia* disease of ginseng: top, crown/shoulder rot; middle, bud rot; bottom, stem canker.



Plate 54. *Rhizoctonia* infections cause rusty or dark brown lesions on roots, similar to *Cylindrocarpon* and *Pythium*. Microscopic examination can determine the cause of infection.



Plate 55. This rusty lesion on a 4-year-old root has been caused by rhizoctonia.

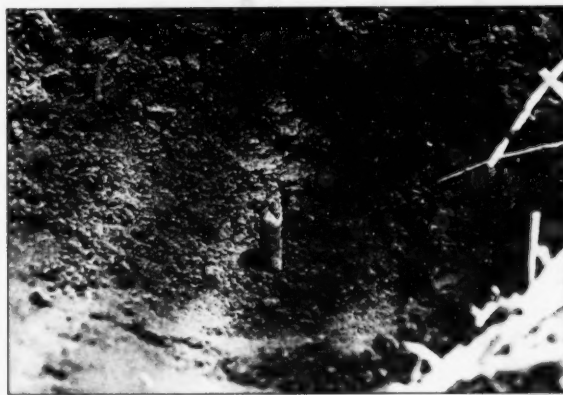


Plate 56. This plant failed to emerge in the spring. Note the bud rot caused by rhizoctonia.



Plate 57. A garden infested with *Rhizoctonia* will have circles of missing plants. Each circle is the result of the fungus moving out from a single focus of disease.

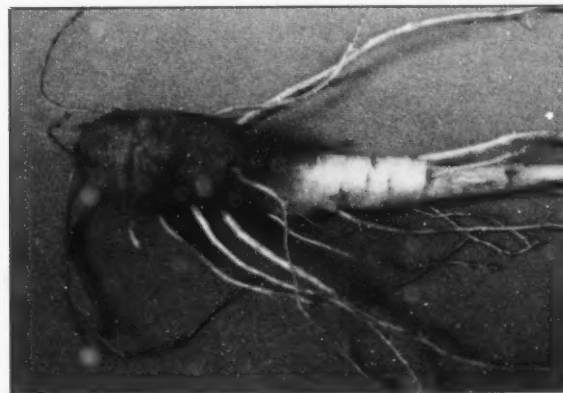


Plate 58. The pinkish-brown rot associated with *Phytophthora* infection is typical of this pathogen.



Plate 59. Roots decayed by *Phytophthora* have a "cheesy" interior. There is no longer any differentiation of tissue common to a root cross-section.

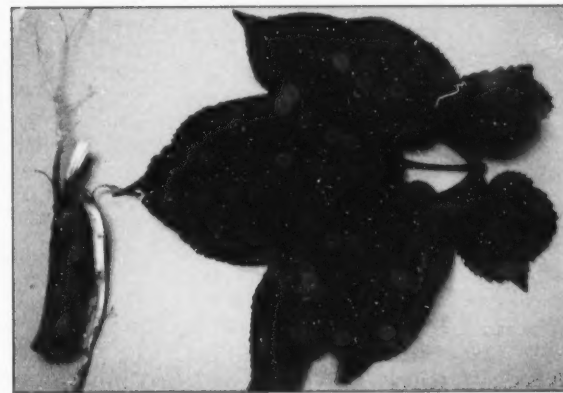


Plate 60. The leaves of plants with phytophthora root rot may remain firm and often have a typical purplish colour.



Plate 61. When rot is advanced, the plant will wilt. Wilting due to phytophthora usually occurs on one leaf first.



Plate 62. This leaflet has a *Phytophthora* infection. Note the water-soaked, puckered appearance of the affected area.

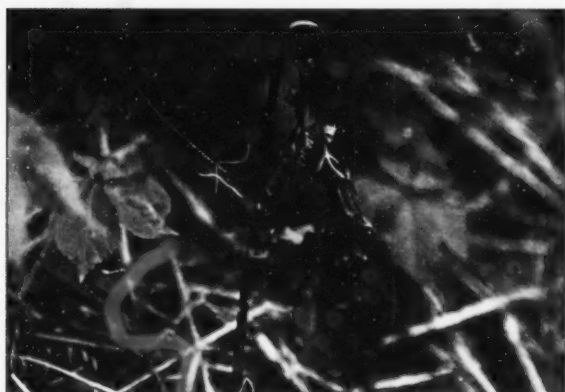


Plate 63. Foliar phytophthora infections can occur on the upper stem and leaves. The entire top of the plant tips over, and the leaves wilt.

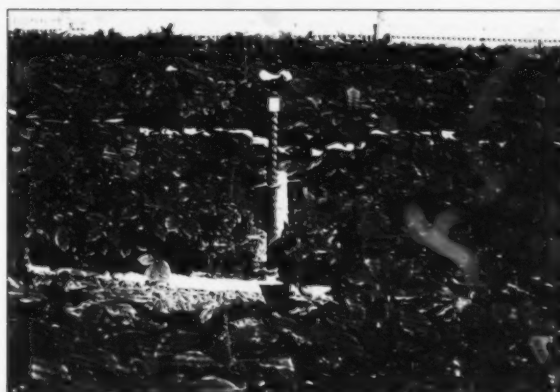


Plate 64. Any wet place in a garden is home to *Phytophthora*. Plants are missing around this leaking sprinkler due to phytophthora root rot.



Plate 65. Plants infected with *Phytophthora* can be found along the edges of trenches where tractor wheels have spread the fungus.



Plate 66. *Alternaria* stem lesions are typically above the straw mulch. They tend to be brittle, causing the stem to fold over sharply.

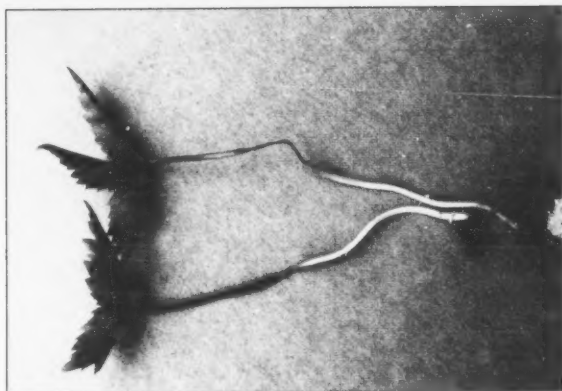


Plate 67. These seedlings have alternaria stem canker. Compare the lesion that is well above the straw mulch to the lesion from *Rhizoctonia* in the plant at the bottom in Plate 53, on page 97.



Plate 68. Alternaria lesions on leaves are tan and dry. They are typically surrounded by a yellow "halo." Sometimes a chlorotic spot is the first sign of a new leaf lesion.



Plate 69. Alternaria stem infection this severe is called "blast." Leaves have dropped, and flower heads have aborted, giving the garden a burnt look.



Plate 70. *Botrytis* sclerotia are common on the straw and old stems in ginseng gardens. The sclerotia germinate in the spring, releasing many conidia that can infect damaged tissue.



Plate 71. As decaying leaves droop, they often come into contact with healthy leaves. The energy of the fungus in the decaying leaf allows it to infect healthy tissue that it contacts.

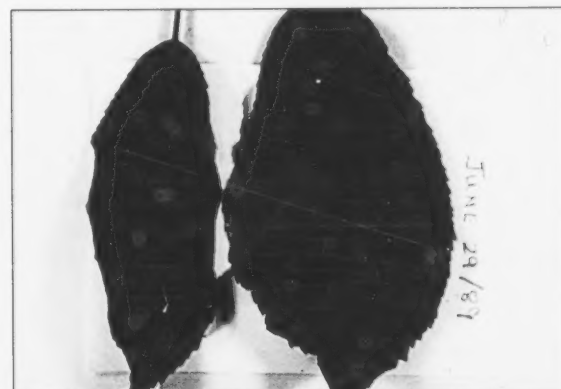


Plate 72. *Botrytis* infections of the leaves resemble phytophthora foliar blight, although tend to be more brown while foliar phytophthora tends to be more water-soaked at first.



Plate 73. Plant tissue damaged by freezing temperatures is susceptible to attack by *Botrytis*. In the humid conditions of the plant canopy, disease can progress rapidly.

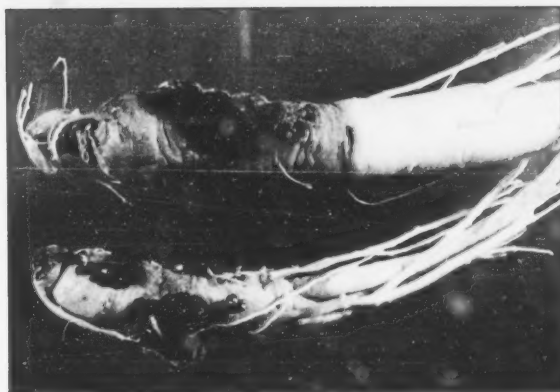


Plate 74. Botrytis root rot is a soft rot that turns affected areas to mush. Sclerotia develop on the botrytis lesions.



Plate 75. This root has the typical blackened, flaky decay associated with severe cylindrocarpon root rot, sometimes called "disappearing root rot."

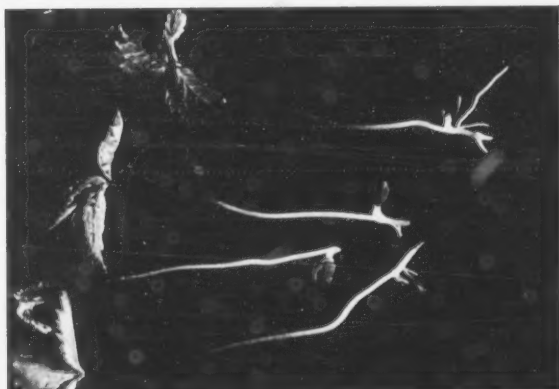


Plate 76. Seedlings infected with *Cylindrocarpon* can show almost no above-ground symptoms, even though the roots are completely decayed.



Plate 77. *Cylindrocarpon* infections in the end of the first year can result in stubby roots where root tips and feeders have decayed.



Plate 78. *Cylindrocarpon* was found on the rusty netting on this root. While no further decay may take place, the root will remain misshapen and unmarketable.

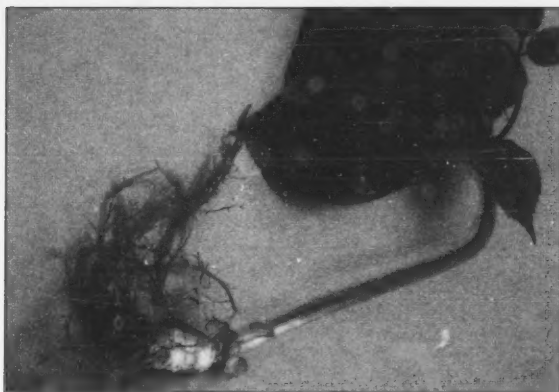


Plate 79. The leaves on this plant give little indication of the cylindrocarpon root rot that has taken place.



Plate 80. Wilt accompanied by drying of the leaves is often associated with cylindrocarpon root rot.

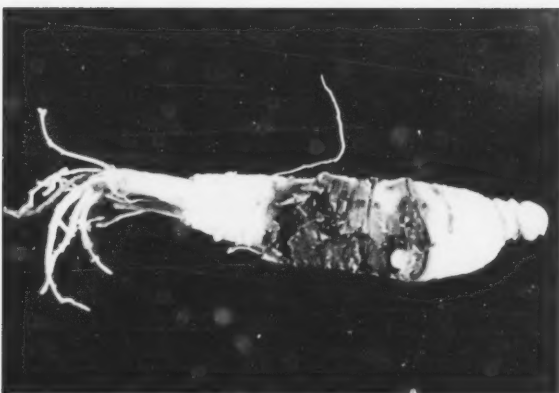


Plate 81. A dark, scaly lesion is typical of cylindrocarpon root rot. It can occur at any point of the root.



Plate 82. The dark scaly lesions associated with cylindrocarpon root rot often have an underlayer of orange-coloured crumbly rot.

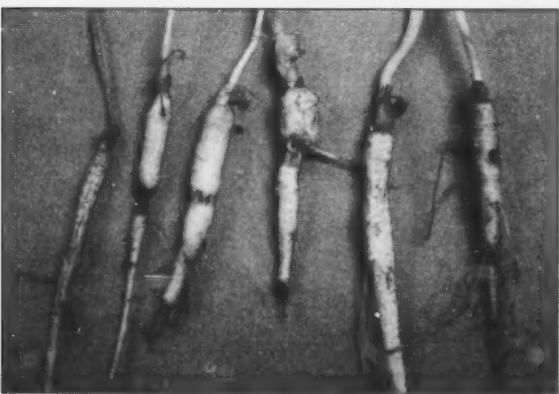


Plate 83. Some strains of cylindrocarpon root rot are weakly pathogenic and cause shallow scabs on the root surface.



Plate 84. Cylindrocarpon infection accompanied by *Rhizopus* results in a sticky, milky decay of the entire root. All that remains is the periderm or "skin" of the root.



Plate 85. Ginseng rust spot can be easily confused with cylindrocarpon or rhizoctonia. It can occur anywhere on the root. It is a response of the root to its immediate environment.



Plate 86. Abiotic rust can result in a deeply decayed area on the root. This is often associated with rust spot caused by low temperature damage.



Plate 87. Rust spot can be superficial. The rust on this root can be scraped off with a fingernail.

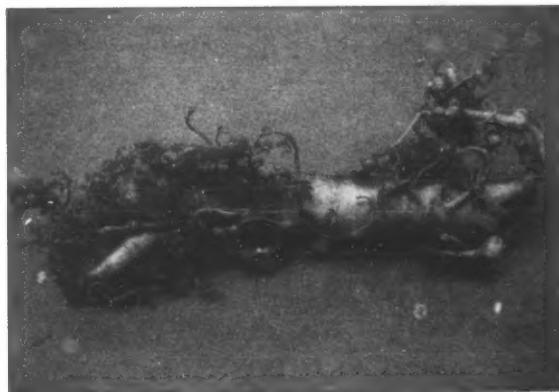


Plate 88. Root knot nematodes cause many galls to form on infected roots.

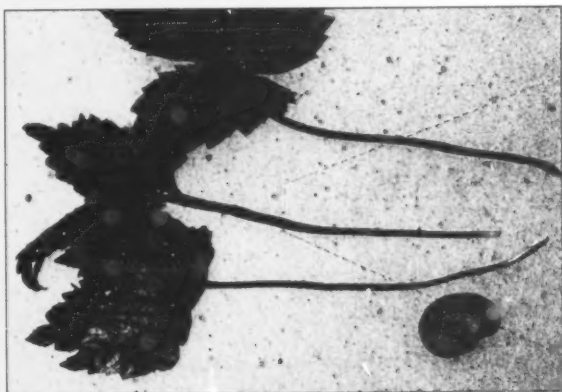


Plate 89. Ginseng seedlings completely severed by a cutworm. Note the typical "C" shape of the cutworm when disturbed. Compare this cutworm larva to the grub in Plate 91, next page.

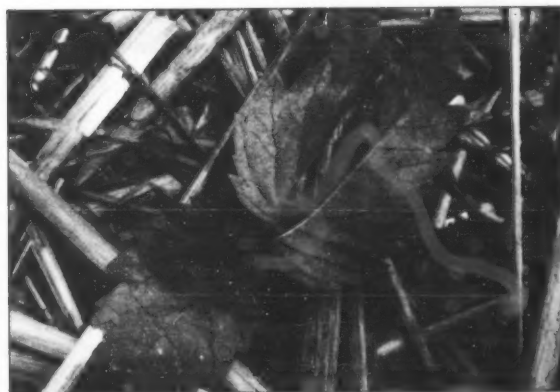


Plate 90. Note the severed top of this seedling lying upside down on the straw. This is typical of cutworm damage.

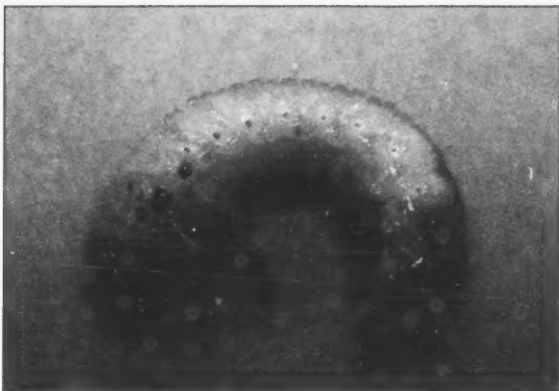


Plate 91. A European chafer "white grub." Larvae like this will consume up to 10 roots each during the seedling year.



Plate 92. A ginseng seedling being "pulled" into the straw as the grub consumes the root. Compare this to the cutworm damage seen in Plate 90, previous page.



Plate 93. Roots consumed by white grubs will leave spaces in the 2-year-old garden.



Plate 94. An adult four-lined plant bug.



Plate 95. Feeding damage from four-lined plant bugs on a seedling. Note the "windows" where all the chlorophyll has been destroyed.



Plate 96. On older leaves, the feeding damage from the four-lined plant bug has less impact. Very little photosynthetic surface has been damaged, compared to the seedling in Plate 95.

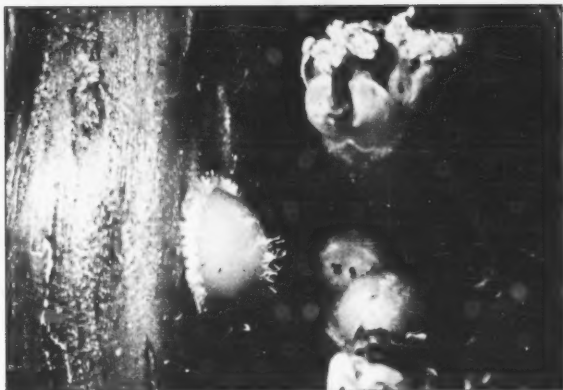


Plate 97. A pit scale, *Asterolecanium arabidis*, on a ginseng stem.

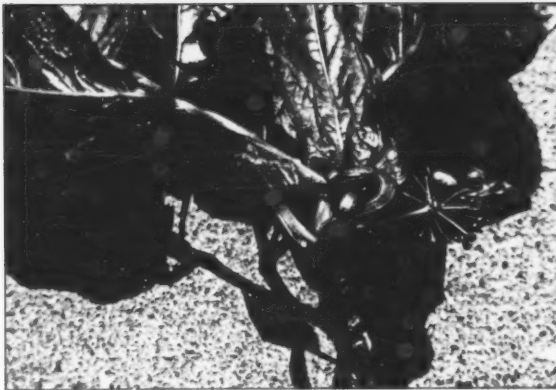


Plate 98. Note the twisted stems and petioles on this plant — the result of feeding by the pit scale.



Plate 99. Note the folded leaf in this canopy. This will act as a refuge for the leaf roller caterpillar.



Plate 100. A larva of one of the leaf roller moths that can feed on ginseng.

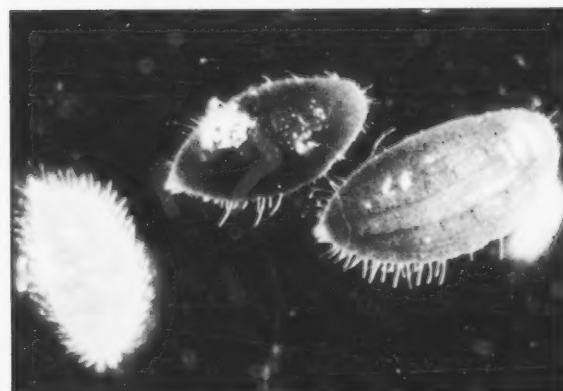


Plate 101. *Acanthococcus* mealybugs have soft pink bodies only slightly covered with a waxy secretion.



Plate 102. Each egg case of the mealybug can contain many small pink eggs.

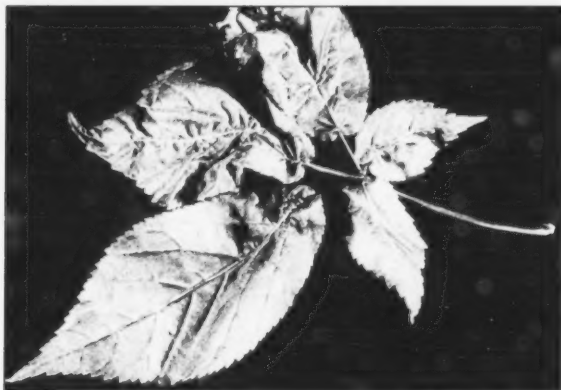


Plate 103. Compare the distortion caused along the leaf midrib by the feeding of the mealybug to the stem and petiole distortion from feeding of the pit scale in Plate 98, previous page.

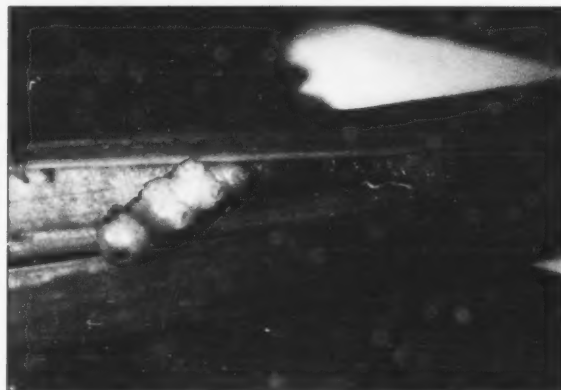


Plate 104. A European cornborer caterpillar inside a ginseng stem.

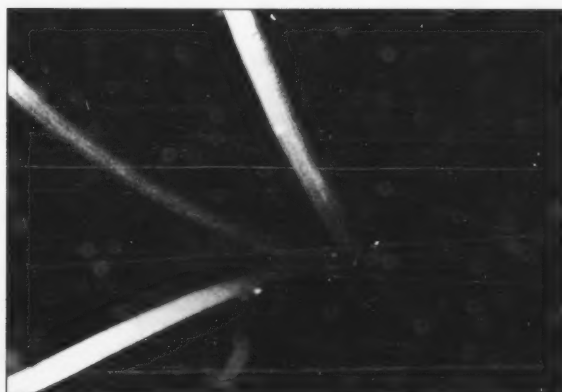


Plate 105. Unknown aphid species on a ginseng stem.

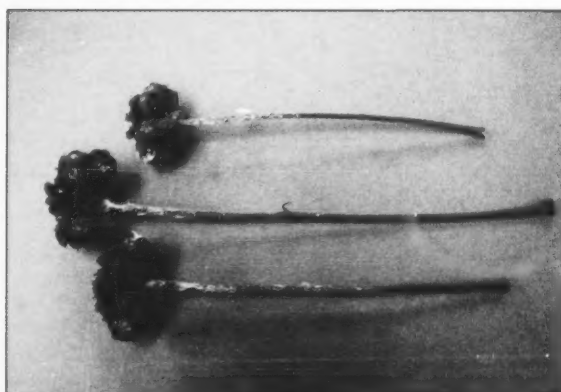


Plate 106. The filamentous, waxy secretion from planthopper nymphs can cover the stems supporting the seed head and the seed head itself.

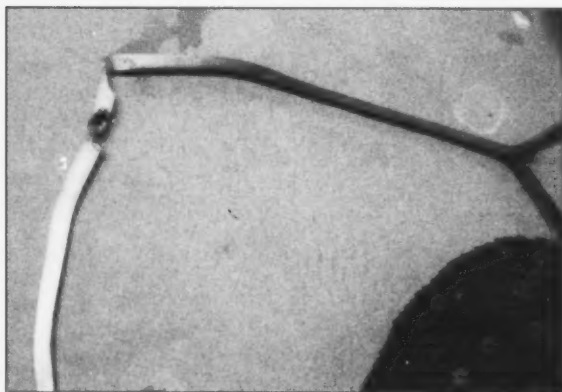


Plate 107. Stem chewed by slugs. Note the ragged hole chewed in the side of the stem. Compare this to the mouse damage in Plate 112, opposite page.



Plate 108. Leaves chewed by slugs will have ragged holes in them.



Plate 109. If present in late summer, slugs can eat into the berry pulp.

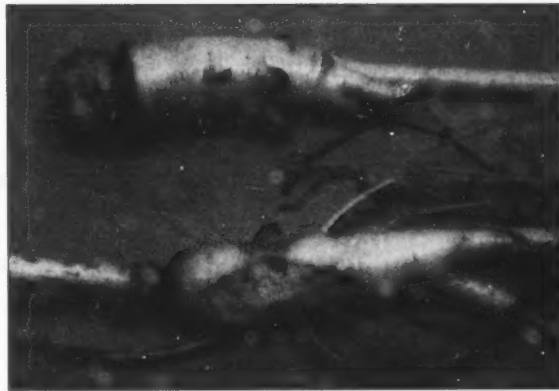


Plate 110. Slugs can also chew roots. Note the excavated area of the root shoulders where slugs have chewed.



Plate 111. Millipedes found in a ginseng field.

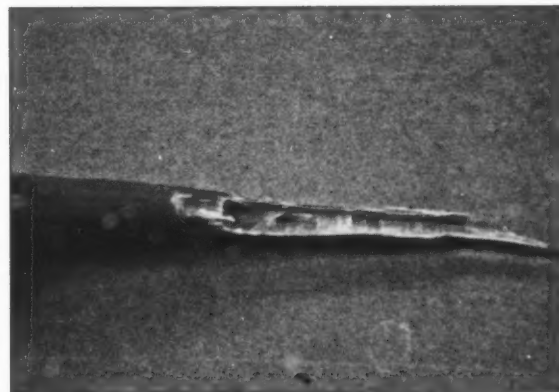


Plate 112. Severed stems with long, elongated areas of chewing are indicative of mouse damage.



Plate 113. The leaves of these seedlings are showing symptoms of heat stress. Note the papery, dry areas of the leaves. Drought stress results in the same symptoms.

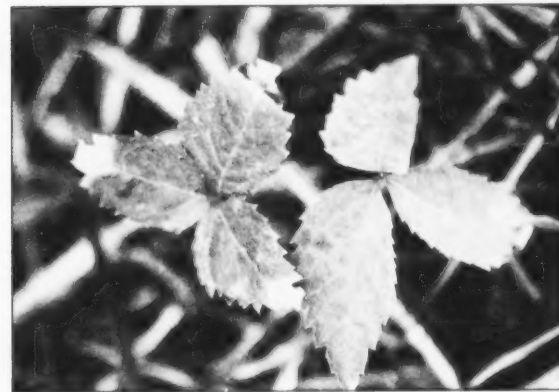


Plate 114. The bleached areas on these plants are a result of air pollution.

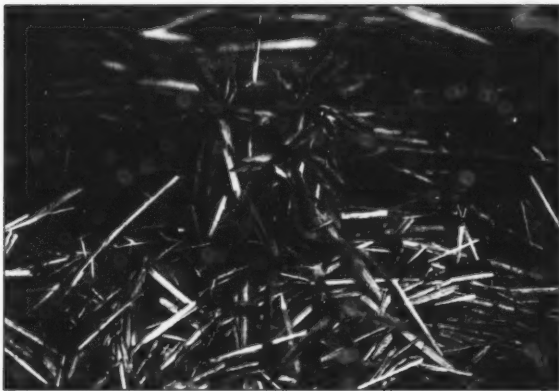


Plate 115. Glyphosate damage to ginseng results in strap-like leaves that never fully unfold.



Plate 116. Mixing foliar fertilizers with some fungicides can result in a foliar burn.

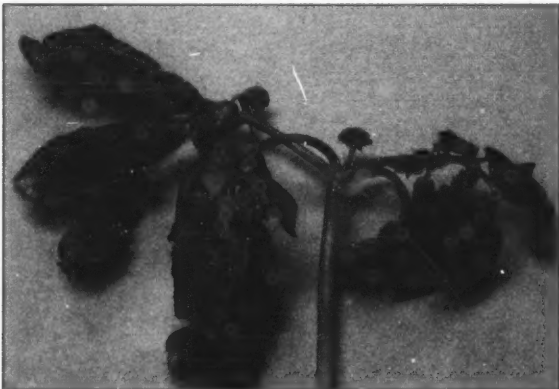


Plate 117. Foliar fertilizers containing cytokinins can cause puckering of the leaves. This plant also has a shiny waxy layer on the underside of the leaves.



Plate 118. Leaf puckering can also be caused by chilling. Compare this to cytokinin damage in Plate 117, and mealybug damage in Plate 103, on page 106.



Plate 119. The most common symptom of low temperature damage is stem-kinking. This can be especially prevalent in a 2-year-old garden but can be present in older gardens as well.



Plate 120. The stem on this plant has become swollen and split. Plants do not usually recover from this damage.

Emergency and First-Aid Procedures for Pesticide Poisoning

For a major spill, a theft or a fire involving a pesticide call the Ministry of the Environment at
1-800-268-6060.

For pesticide poisonings and pesticide injuries call the Poison Information Centre:
Toronto 1-800-268-9017
1-877-750-2233 (TTY)

PREVENT ACCIDENTS

- **Read the label.** Follow all the precautions the label recommends. Read the First Aid section of the label **BEFORE** you begin to handle any pesticide.
- **Make sure that someone knows** what pesticides you are working with and where you are.
- **Keep a file of labels and product Material Safety Data Sheets (MSDS) for the pesticides you use.** Make sure everyone knows where to find this in case of an emergency.
- **Post emergency numbers near all telephones.**
- **Keep clean water, paper towels, extra gloves and clean coveralls close by** in case you spill pesticide on yourself.

If someone has been working with pesticides and you see any possible symptoms of pesticide poisoning or injury, take emergency action immediately.

IF AN ACCIDENT OR POISONING HAPPENS

- Protect yourself from injury first.
- Stop the exposure to the pesticide. Move the victim away from the contaminated area.
- Check the four basic facts — identify the pesticide, the quantity, the route of entry and time of exposure.
- Call an ambulance or the Poison Information Centre.
- Start first aid. This is not a substitute for professional medical help.
- **Provide the label, MSDS sheet or container to emergency personnel** at the scene — or take it with you to the hospital. Do not transport pesticide containers in the passenger compartment of the vehicle.

Cette publication hautement spécialisée n'est disponible qu'en anglais en vertu du règlement 411/97, qui l'exempte de l'application de la *Loi sur les services en français*. Pour obtenir de l'aide en français, veuillez communiquer avec le ministère de l'Agriculture, de l'Alimentation et des Affaires rurales au numéro 1 877 424-1300.

FIRST AID

If a pesticide comes in contact with skin:

- remove all contaminated clothing; wash skin thoroughly with lots of soap and warm water
- dry skin well and cover with clean clothing or other clean material.

If pesticide comes in contact with eyes:

- hold eyelids open; wash the eyes with clean running water for 15 minutes or more.

If pesticide was inhaled:

- move the victim to fresh air and loosen tight clothing
- give artificial respiration if the victim is not breathing.

Do not breathe in the exhaled air from the victim — you could also be poisoned.

If a pesticide was swallowed:

- call the Poison Information Centre **IMMEDIATELY.**

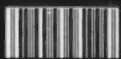
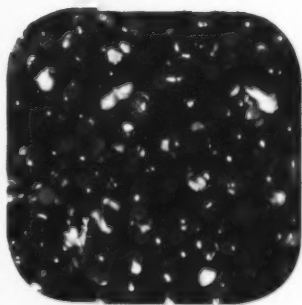
Emergency numbers are listed at the front of each Bell telephone directory.

To obtain copies of this or any other OMAFRA publication, please order:

- online at www.serviceontario.ca/publications
- by phone through the ServiceOntario Contact Centre, Monday to Friday, 8:30 AM to 5:00 PM ET
 - 416-326-5300
 - 416-326-3408 (TTY)
 - 1-800-668-9938, toll-free across Canada
 - 1-800-368-7095 (TTY), toll-free across Ontario
- in person at ServiceOntario Centres across Ontario

Published by the Ministry of Agriculture, Food and Rural Affairs
Queen's Printer for Ontario, 2009
Toronto, Canada

ISSN 1496-502X RV 10-09-1M



www.ontario.ca/crops

